GEOCHEMISTRY OF RECENT LAKE MICHIGAN SEDIMENTS

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COVER PHOTOS: On left, Lake Michigan bottom sediments classified through cluster analysis (see fig. 37 in text); on right, the *C.S.S. LIMNOS.*

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ABSTRACT

This report contains the results of the first truly systematic sediment sampling of Lake Michigan. Distributions are reported for concentrations of 48 chemical elements, for pH and Eh, and for grain size of 286 samples. Chemical analyses were made in two independent laboratories using a variety of analytical techniques; therefore, the results should be of superior accuracy.

Evaluating measurements of grain size and chemical composition led to classifying Lake Michigan surficial sediments by origin, as being from either depositional or nondepositional areas. The depositional areas include a number of sub-basins that have similar sediment properties and chemical composition, even though they are separated by topographic features on the lake bottom.

The distribution of trace elements, including heavy metals of anthropogenic origin, correlates positively with the abundance of fine-grained sediment. Clay minerals and organic materials are hosts for the relative enrichment of many of the trace elements in surficial sediments of the depositional basins.

Statistical techniques, including correlation, factor analysis, and cluster analysis, further demonstrate the importance of clay-sized material and organic carbon in controlling the distribution of many elements. The role of ferromanganese nodules in concentrating arsenic and barium is evident, particularly in Green Bay. The areal distribution of three cluster-analysis groupings is in good agreement with areal distributions of sediment type, grain size, and trace-element content.

INTRODUCTION

The investigation of the sediments at the bottom of a lake provides a record of past geologic and climatic events that have influenced the lake and its associated drainage basin. The most recent sediments of a lake are indicators of man's impact on the surrounding watershed and emphasize the complex nature of interaction between chemical, biological, and physical processes that affect the distribution of sediments and their associated minerals and chemical species.

Since 1969 the Illinois State Geological Survey (ISGS) has been studying the geology and geochemistry of southern Lake Michigan in a program concentrating on the part of the lake that lies within state boundaries. Since 1968 the Canada Centre for Inland Waters (CCIW) has been conducting a sampling program over all five of the Laurentian Great Lakes. In 1975, through the coordinating efforts of Dr. David L. Gross (ISGS) and Dr. Richard L. Thomas (CCIW), these two programs were joined in a cooperative study of Lake Michigan that resulted in this report, as well as several others.

This study was carried out at the Illinois State Geological Survey, where most of the chemical analyses were made. Dr. Richard L. Thomas (CCIW) provided the facilities of the *C.S.S. LIMNOS*, the research ship for the Canada Centre for Inland Waters. Dr. Thomas and Dr. Gross (ISGS) served as scientific officers during collection of the samples. Dr. Thomas also supplied analytical and sedimentologic data and maps.

This report is being used by the Illinois Division of Water Resources as a matching contribution to the Great Lakes Environmental Planning Study of the Great Lakes Basin Commission.

Basic limnology

Freshwater lakes contain 0.009 percent of the total water in the biosphere; saline lakes contain 0.008 percent; and oceans contain 97.6 percent. Lakes occupy less than 2 percent of the continental surface area. Today there are only 15 "large" lakes (those with surface areas of more than 15,000 sq km) and only a few hundred lakes with a surface area of more than 50 sq km. The majority of lakes are much smaller.

In terms of geologic time, even the largest lakes are relatively transitory. The Great Lakes of North America, for example, have existed for only about 8,000 years. Most large lakes exist for about 1,000 to 10,000 years; smaller lakes and playas may persist for only a few hundred years. There are some notable exceptions, however, such as Lake Baikal in Siberia, which has existed with the same lacustrine environment since the early Tertiary and is the world's deepest and largest freshwater lake.

The origins of lake basins and their morphology influence the nature of the drainage basin, the degree of shoreline development, the lake bottom contour, and, ultimately, the productivity and life expectancy of the lake. The origins, distributions, and forms of lake basins are discussed in detail by Hutchinson (1957), Reeves (1968), Wetzel (1975), and Cole (1975).

Tectonic processes of downwarping and faulting created structural basins that controlled the development of many lake systems. Tectonic movements have caused uplift in marine regions, isolating several large lake basins such as the Caspian Sea in Europe and Lake Okeechobee in Florida. Glacial activity, particularly during the Pleistocene, created an immense number of lakes, many of which are still in existence. The effects of continental glacial scouring and crustal rebound on the formation of lakes is illustrated by the formation of the Laurentian Great Lakes of North America. Lakes are also created by fluvial, eolian, alluvial, volcanic, coastal, and solution processes. Such lakes normally are not as common as the others, but can be important locally.

Although classification of lakes can be useful, most lake basins require multiple mechanisms to account for their origins. The stratification of temperature and density in lakes is the dominant regulator of most physical and chemical cycles and of lake productivity. The cyclic nature of lakes is often preserved in lake sediments, which helps in recognizing ancient lake deposits.

Lakes normally have a freely circulating, warmer, less dense surface layer—the epilimnion—and an undisturbed, colder, denser, deeper layer—the hypolimnion. Because of seasonal temperature variations, a thermally driven circulation can mix these layers and overturn the lake waters. The size and depth of lakes account for their different thermal cycles: amictic lakes are permanently ice covered; monomictic lakes have one yearly circulation; dimictic lakes undergo turnovers in the fall and spring; oligomictic lakes have rare or irregularly spaced overturns; and polymictic lakes have nearly constant circulation.

Often lakes do not undergo complete circulation and the bottom layers become permanently stratified. A permanently stratified bottom layer is important for the preservation of organic matter. These lakes, known as meromictic lakes, can be formed by a number of processes. For example, the intrusion of saline water into a freshwater lake or the intrusion of fresh water into a saline lake can cause meromictic stratification. There are several modern examples of the discharge of saline waters into the bottom layers of freshwater lakes. Saline lakes in arid regions often receive fresh waters from floods; this produces a pronounced stratification that can persist for many years. Biological decomposition of organic matter during its sedimentation can release enough dissolved substances to create a meromictic lake. In addition, lakes are often made meromictic temporarily by biological processes that are controlled by climatic or productivity changes. The sedimentary record produced from such a lake over a significant span of time would be cyclic.

Lacustrine systems often undergo fluctuations in water level that can be quite drastic. Seasonal variation in rainfall produces a periodicity in the amount of sediment reaching a lake and therefore the sediment record in the lake. Worldwide changes in climate distribution can also alter precipitation levels and are significant considerations in many areas, but the interval of any regular climatic cycle usually cannot be determined with confidence. Changes in drainage patterns can also result in significant changes in lake water levels.

Water movement in lakes involves turbulent flow, which is frequently oscillatory in both direction and magnitude. The shape of the lake basin and the amount of surface area exposed to the wind affect the magnitude and direction of the water movement and consequently the deposition. Internal seiches or waves, often of large period and amplitude, produce deep water currents in large lakes. These currents can lead to both horizontal and vertical transport of dissolved and particulate matter. Tides are sometimes detected, but they are responsible only for an insignificant part of the water movement, even in the largest lakes.

The chemical classification of lakes is based on salinity and on ionic ratios among the dissolved constituents. In lakes with outflowing drainage, the chemical composition of the lake is governed by contributions from the atmosphere and from inflowing surface and subsurface waters. Lakes fed by rivers that drain acidic rocks usually have low levels of dissolved solids. Lakes fed at least in part by rivers that flow over calcareous deposits have waters and sediments rich in alkaline earths. In closed basins, salinity is often greatly enhanced by evaporation, and ionic ratios are modified by the precipitation of salts. The chemical properties of individual anions and cations, the role of inorganic and organic carbon, and the effect of major, minor, and trace elements on biological productivity have been studied extensively (Wetzel, 1975; Hutchinson, 1957).

The biological or trophic classification of lakes is based on the rate of recycling inorganic plant nutrients. Two common biological classifications are eutrophic and oligotrophic. Eutrophic lakes have a high surface-to-volume ratio, are usually rich in plant nutrients, and have high organic productivity. In contrast, oligotrophic lakes have a low surface-to-volume ratio, are low in plant nutrients, and are low in organic productivity. It is important to realize that any particular lake will move through a series of different classifications as it ages.

Organic geochemistry of lakes

Knowledge of the molecular composition of the organic matter of Holocene sediments offers a means of interpreting changes in lake conditions. Many assumptions must be made in the interpretation of these data, however, and the analysis, until recently, has been difficult to carry out. The body of knowledge on the molecular nature of organic matter in lakes was reviewed by Vallentyne in 1957. Later (in 1969), he pointed out the almost complete lack of theoretical or empirical rules for predicting the lacustrine stability of organic compounds. For a sedimentary constiuent to be useful it must have stability and resolvable information on the time, place, and mechanism of its synthesis (Vallentyne, 1969). Anaerobic conditions favor the preservation of organic materials over geological periods of time, but particular groups of compounds such as amino acids may not persist unchanged even in this generally favorable environment. It is a principal goal of chemical taxonomy to correlate particular compounds in sediments with particular contemporary organisms containing the same compounds, and part of the correlation can often be quite specific.

Otsuki and Hanya (1967) and Ishiwatari (1973), among others, have attempted to follow the behavior of the humic substances in Holocene sediments. "Humic acids," a term first used in soil science, refers to a group of compounds that can be extracted from soils by an alkaline solution and then precipitated upon acidification. They are polymers of large and variable molecular weight and are poorly defined structurally; their role in complexing metal ions will be discussed later in the text. Ishiwatari (1973) characterized fractionated humic acids by means of infra-red spectroscopy and nuclear magnetic resonance. He noted differences among humic acids from different lakes, but made little attempt to identify the sources of those acids.

Otsuki and Hanya (1967) discussed the chemical character of the humic material in less detail than Ishiwatari, but were more interested in distinguishing autochthonous and allochthonous humic substances. Infra-red spectra were compared for soils, Holocene sediments, and a series of organisms that might have contributed precursor organic compounds for humic acids. They found that the humic content of Holocene lake sediments more closely resembles that of potential source organisms than that of soil.

Kemp (1971), Kemp and Mudrochova (1973), Van der Velden and Schwartz (1976), and Dungworth et al. (1977) analyzed Holocene sediments, in particular those of Lake Ontario, for amino acids and other nitrogen-containing organic compounds. Kemp (1971) outlined the distribution of organic carbon and total nitrogen in Lakes Ontario, Erie, and Huron in the top cm of sediment. The amount of organic material was found to be proportional to the clay-sized fraction of sediment and to decrease with depth in the sediment column. Kemp and Mudrochova (1973) studied amino acid concentrations in bottom and suspended sediments and in zooplankton in Lake Ontario, and concluded that 90 percent of the lake's organic matter is autochthonous. They were able to isolate proteins and peptide chains that were not significantly different from their precursors. They did not speculate on either the rate or the pathway for degradation of the nitrogen compounds.

Van der Velden and Schwartz (1976) analyzed sediments from Lakes Erie and Ontario, and from Lake Constance (in the Netherlands) for purine and pyrimidine. The distributions they observed for these three lakes were similar, roughly following the organic carbon distribution in each case. They made little mention of the rate of decomposition of these compounds or who they could be related to specific sources. Dungworth et al. (1977) made detailed analyses for several organic nitrogen compounds in a single deep core from Lake Ontario. Amino acids made up 50 percent of the organic nitrogen at the top of the core, and the other compounds were rather uniformly distributed with depth.

Man-made organic residues will resemble naturally occurring compounds if they originate in waste from sewage treatment, but they may be quite distinct if they are synthetic organic compounds, such as pesticides. Because the time when a particular insecticide was first used in a given region is often known, pesticide residues may serve as markers for sedimentation rates and other transport parameters. Leland, Bruce, and Shimp (1973) reported that high concentrations of pesticide residues observed in the sediments of southern Lake Michigan coincide with high concentrations of organic carbon, fine particulate matter, and trace element accumulations. The residues are most concentrated in the first 2 cm below the sediment-water interface, but are also high in the 6- to 12-cm interval, suggesting either a change in sedimentation rate, biological mixing, or physical mixing. The availability of this reservoir of pesticides in the sediment to organisms is uncertain. These residues could be consumed by benthic organisms and concentrated further by aquatic predators higher in the food chain.

Inorganic geochemistry of lakes

The inorganic chemical composition of lacustrine sediments are frequently used to distinguish different inputs, particularly those that are anthropogenic. The analytical procedures used are less tedious than those used for the identification of organic compounds, and multi-element techniques such as instrumental neutron activation analysis make it possible to accumulate data simultaneously for many elements. Some trace metals, such as lead, can be directly attributed to anthropogenic sources, but the origins of other trace metals are uncertain. Uncertainty about the exact chemical form of the element in the depositional environment is one factor making it difficult to trace the element back to its sources.

Several studies have addressed these concerns. Bortleson (1971) and Bortleson and Lee (1972, 1975) examined whether the chemical changes along sediment cores from a number of Wisconsin lakes could be related to cultural activities within the watershed. They found that the distribution patterns for organic carbon, P, Al, Fe, and Mn, and the Ambrosia (ragweed) pollen count were similar in each core. They also found an increase in organic carbon and thought it indicated an increase of biological productivity of the lake, but they found it difficult to determine whether the increase was due to allochthonous or autochthonous organic production.

Jackson and Nichol (1975) studied 19 lakes in the Canadian northwest to determine if the topography and mineralogy of bedrock in each watershed were reflected in the sediment of the corresponding lake. Analyses were made for Cu, Pb, Zn, Co, Ni, Fe, Mn, Ag, As, and organic carbon. They found that sorting by wave action and coprecipitation with hydrous iron and manganese compounds modify trace metal distributions within a given lake, and that these distributions can be correlated with dissolved oxygen content, pH, and organic carbon content.

Hopke (1976) and Hopke et al. (1976) determined the clay mineralogy, grain size distribution, and concentrations of 15 elements in a suite of 98 sediment samples from Lake Chautauqua, New York. Most of the element abundances had high positve correlations with abundances of clay-sized particles. Iron-manganese nodules and crusts were present; the high levels of arsenic and bromine that were present were attributed to human intervention. By using common factor analysis and cluster analysis, elements and samples could be grouped according to depositional environment and source material.

Kemp and Thomas (1976) used chemical data to discuss man's impact on Lakes Ontario, Erie, and Huron. Enrichments of Hg, Pb, Zn, Cd, Cu, Be, V, organic carbon, Ni, and P at these locations are believed to be anthropogenic. Terrigenous sediment inputs yield fairly uniform distributions of Si, Al, Fe, Mg, Ti, K, and Na. Winchester and Nifong (1971) first noted that dry and wet despositions from the atmosphere were important as sources of several elements in Lake Michigan. They maintained that higher trace-element contents observed at several sampling sites could be best explained as resulting from atmospheric loading—possibly from distant sources. These authors believed that dispersion pathways of terrigenous material entering the lake system were fairly well known, whereas anthropogenic inputs were poorly understood. The distribution of many metals within a lake will be affected by adsorption on particles and by complexation by organic ligands.

Baker-Blocker, Callender, and Josephson (1975) studied the relationships among trace element concentrations, organic carbon content, and mean grain size of the surface sediments at Grand Traverse Bay, Lake Michigan. They found that the mean grain size can be used to define the depositional environment, which is responsible for the distributions of organic carbon and trace metals. They also noted that sediments containing high organic carbon and high trace metal levels were not observed in high-energy areas of the bay.

Using data from a variety of source inventories, Klein (1975) proposed a model of mass balance for trace elements in Lake Michigan. Soil was found to account for the loading of Al, Co, Cr, Fe, La, Mn, Si, Sc, and Th, whereas aerosol deposition accounted for the loading of

Ag, As, Br, S, and Zn. The model did not adequately consider the volatility of the elements, and therefore predicted Hg, Sb, and Se concentrations that were too high. Predicted values for Ca, Na, Mg, and Cl were too low because inputs from rock weathering and from the use of road salt had not been considered.

Shimp, Leland, and White (1970) and Shimp et al. (1971) were the first to show positive correlations between organic matter and accumulations of trace elements in the surficial sediments of Lake Michigan; they were also among the first to demonstrate this process in freshwater lakes in general. Organic matter and anthropogenic influences were stressed as important factors in the distribution and transport of trace elements.

Leland, Shukla, and Shimp (1973) evaluated the factors affecting the distribution of lead and other trace elements in southern Lake Michigan, and summarized much of the work done on Lake Michigan up to that time by the Illinois State Geological Survey. They considered how organic complexes, clay minerals, calcium carbonate precipitation, biological concentrations of selected trace elements, hydrous oxides, and relative solubilities were significant to the lacustrine environment. They concluded that As, Br, Cr, Cu, Hg, Pb, and Zn are anthropogenic inputs that are sorbed by suspended particles, which are then transported by waves and currents to the sedimentation site. They outlined the areas where these trace metals accumulated in southern Lake Michigan, and collected the suspended sediments. Analysis of these sediments showed elevated levels of the same trace elements, plus greatly elevated concentrations of organic matter, further supporting the conclusion that certain trace elements entering the lake are anthropogenic in origin and are associated with organic matter.

Torrey (1976) reviewed the published reports on the chemistry of Lake Michigan. He studied how changes in water quality and sediment chemistry, attributable to cultural and natural influences, were related to factors that controlled thirty chemical substances within the lake. Trace metal concentrations in the surficial sediments were found to increase from nearshore to offshore areas. Because data was so limited for the entire lake, however, no conclusions could be made by comparing the southern basin to other areas in the lake.

The work by Andren and Harriss (1975) on Hg consists of a group of studies that emphasizes the importance of metal-organic interactions for toxic metal mobility. These interactions have been studied for many years by soil scientists interested in the uptake and mobilization of trace metals that are important as plant nutrients (Schnitzer and Khan, 1972; Schnitzer and Skinner, 1967; Baker, 1973). Recent studies of natural water include those by Reuter and Perdue (1977), Nissenbaum and Swaine (1976), and Cline and Upchurch (1973).

Nissenbaum and Swaine (1976) found that several elements occur in variable, and often high concentrations in the humic fraction of natural sediments. They noted that little is known at present about the chemical bonds or physical interactions that bind the metals to this organic matrix, or what effect the physical or chemical state of the inorganic matrices will have on the metal-humic fraction interaction.

Reuter and Perdue (1977) presented a review of the literature concerned with the abundance and molecular nature of dissolved organic compounds in natural waters and the types of metal-organic interactions believed to be involved. Their study primarily explored the origin and characteristics of humic material in soils and natural waters, and the extent of metal interactions with the humic material. Fractional elution of soils by rain was thought to be the main source of dissolved humic substances in rivers, although the human contribution from sewage treatment can be very significant locally. The acidic nature of humic polymers is thought to be the reason that humic metal complexes are more stable than inorganic metal complexes.

Cline and Upchurch (1973) proposed that heavy metals migrate upward through a sediment column as a result of dewatering during compaction and complexation by bacteria. If true, this implies that higher concentrations of metals would be expected at the sediment-water interface—a result that could be misinterpreted as an increase in an anthropogenic source.

The direct correlation between the abundance of trace metals and the abundance of biological material observed in freshwater lakes is not well understood. There are problems involved in determining low levels of trace metals in plankton; this was evident in the work of Martin and Knauer (1973). Wetzel (1968, 1975) noted that chelation of trace elements may radically affect the physiologic availability of many essential ions, which in some cases reduces concentrations to below those that are required by a particular algal species. Gorham et al. (1974) studied the relationships between the algal standing crop and the water and sediment chemistry of the English lakes. Using pigments preserved from algal populations as well as chlorophyll derivatives, they found that sediments in productive lakes contain more sulfur and are more likely to have compounds of algal origin preserved in anaerobic bottom sediments. They postulated that the differences between algal chlorophylls can be used in fossil pigments and pigment ratios to deduce the past productivity of a lake.

REGIONAL AND TEMPORAL SETTING

Lake Michigan is the third largest of the Laurentian Great Lakes and the sixth largest freshwater lake in the world, with a surface area of 58,000 sq km and a drainage area of 175,860 sq km. It has a coastline, including islands, of 2,640 km, a maximum length of 494 km, and a width of 190 km. The mean depth is 85 m with a maximum depth of 281 m, i.e., 104 m below sea level. Lake Michigan receives most of its water from direct precipitation and runoff from numerous tributaries. It has the smallest drainage of the Great Lakes, with an outflow of 1,560 sq m/sec at the Straits of Mackinac and a small diversion to the south at the Chicago River.

The complex topography of the lake floor (summarized recently by Wickham et al., 1978) is shown in figure 1, plotted as mean depth of water below mean lake level. Utilizing prominent topographic features, the lake has been subdivided (Emery, 1951; Wickham et al., 1978) into a southern basin, the Mid-lake High, a northern basin, Green Bay, and the straits area.

The southern basin is smooth sided and has a maximum depth of 163 m. On the basin's eastern side, the lake floor descends rapidly to deeper water, whereas the western and southern sides of the basin slope more gently. A steep rise begins approximately 15 km from the eastern shore at Benton Harbor, Michigan, and extends to the Mid-lake High.

The Mid-lake High is an area of bedrock-controlled topographic highs in the center of the lake east of Milwaukee. In some places, the bedrock is as shallow as 22 m below the present level of the lake. The bedrock knobs are covered with till and other glacial sediments. Deepwater basins partially flank the Mid-lake High on both the east and west. The area appears to be composed of resistant Silurian and Devonian carbonate bedrock that was not extensively eroded by Pleistocene glaciers.

The topography of the northern basin is more irregular than that of the southern, with small ridges and valleys throughout. A generally smooth and uniform slope extends down the western side of the basin to a depth of approximately 180 m. Hough (1958) suggested that the western slope of the lake correlated with the dip slope of the resistant Niagaran dolomite (Silurian). On its eastern side, the northern basin is bordered by an offshore bedrock escarpment that extends north to south along a chain of islands in northeastern Lake Michigan.

Green Bay is a relatively shallow body of water; its mean depth is approximately 25 m. The bay is separated from Lake Michigan by the Niagaran Escarpment (Silurian dolomite), which forms a peninsula and a chain of islands on the eastern side of the bay.

In the straits area, the lake floor has steep ridges, narrow depressions, and bedrock pinnacles. In the extreme northern end of the lake, most of the lake bottom is exposed bedrock. A narrow canyon that once served as a drainageway extends across the lake bottom from the Straits of Mackinac to a shallow divide 72 km west of the straits (Stanley, 1938). The irregular topography of the straits area results mainly from differential erosion of the lake floor by glacial ice movement (Shepard, 1937; Emery, 1951). By extrapolating from the northwestern region of southern Michigan, an alternating succession of resistant and nonresistant rock units within the Traverse Group (Devonian) is inferred under the straits area. Subsidence into solution cavities within the underlying salt and gypsum beds of the Silurian Salina Group also may have affected the topography of the straits area (Hough, 1958).

Hough (1958) summarized what was then known of the geological history of the Great Lakes. More recent studies by Dorr and Eschman (1970), Wickham et al. (1978), Lineback, Gross, and Meyer (1974) and Lineback, Dell, and Gross (1979) describe in detail the glacial and post-glacial sediments of Lake Michigan and discuss their relationship to the glacial history of the area.

The Great Lakes owe their present shapes, bottom topographies, and drainage patterns to a complex series of glacial advances and retreats, which caused changes in drainage patterns and lake levels and later crustal uplift. Mortimer (1975) discussed the physical limnology of Lake Michigan as it related to basin geomorphology, water budget, and light penetration, and reviewed the interaction between wind-induced turbulence and heat-related buoyancy. Torrey (1976) studied the physical and dynamic processes that affect the chemistry of Lake Michigan.

The surface circulation of Lake Michigan consists principally of counter-clockwise flows in both the northern and southern basins, for example, along the eastern shore from south to north (Callender, 1969). The bottom currents are complex and variable (Ayers et al., 1958). Two different surface current patterns exist in the southern basin (Bellaire and Ayers, 1967); which one is in force at any given time depends on prevailing wind directions. Lerman (1978) discussed how hydrodynamic models have been used to study Lake Ontario, and how these models have been used to study the generation of internal waves or seiches in Lake Michigan.

Gatz (1975) and Gatz and Changnon (1976) described the atmospheric environment around Lake Michigan and constructed wind rose diagrams for the four seasons at four locations around the lake. The wind patterns are not only important in producing surface circulation patterns, but they also determine the amount of atmospheric pollution reaching different parts of the surface of Lake Michigan. Sievering et al. (1979) have measured this atmospheric loading in the southern basin of Lake Michigan, and have discussed the control meterologic conditions have on the deposition of atmospheric aerosols in the lake.

The sedimentation rates in Lake Michigan are generally low, and the lake can be thought of as sediment starved. Sedimentation rates obtained by Lineback and Gross (1972) ranged from 0.4 to 3.2 mm/yr (based on thickness of the Waukegan Member in the southern basin). Using fossil pollen evidence, King, Lineback, and Gross (1976) estimated the average sedimentation rate to be 0.5 mm/yr in the central area of the southern basin, and 0.9 to 1.02 mm/yr along the eastern side of the lake. Using lead-210 measurements, Edgington and Robbins (1976), Robbins and Edgington (1975) and Christensen and Chien (in press) obtained sedimentation rates in the range of 0.1 to 4.1 mm/yr, with the highest value being 5.2 mm/yr in Green Bay. This agreement among different methods indicates that the sedimentation rate in Lake Michigan has not changed significantly over the last 7,000 years (Robbins and Edgington, 1975).

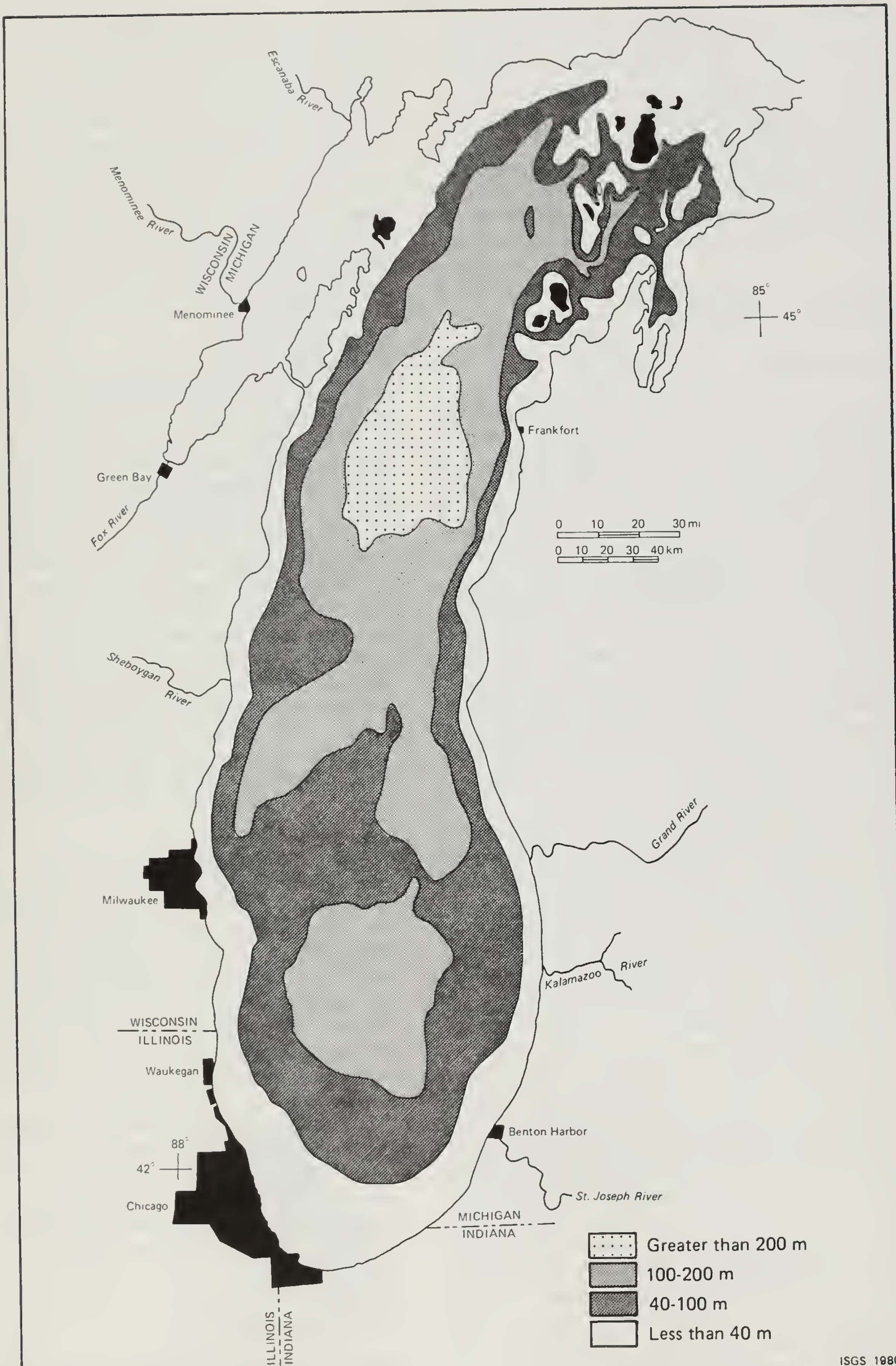

Figure 1. Generalized water depth.

Most of the tributaries entering Lake Michigan are small; only eight have mean discharges of over 1,000 cu ft/sec. These rivers contribute to the trace-metal balance of the Great Lakes (Fitchko and Hutchinson, 1975; Robbins, Landstrom, and Wahlgren, 1972). Many of the rivers entering Lake Michigan from the east first pass through small glacial lakes that serve as sediment traps. One such river is the Grand River, on the east side of the lake, which has had high trace-element loadings, as do the Menominee, Milwaukee, and Kinnickinnic Rivers on the west side.

EXPERIMENTAL METHODS

Shipboard procedures

The conclusions of this project are based on samples and measurements obtained during an extensive research cruise by the Canada Survey Ship *LIMNOS* in August, 1975. Unlike earlier geological investigations of Lake Michigan, this cruise consisted of a systematic traverse over the entire lake basin, including Green Bay (fig. 2). Grab samples were collected at the intersections of a 12-by-12-km Universal Transverse Mercator (UTM) grid over most of the lake bottom; a more detailed 7-by-7-km UTM grid was used in Green Bay and in the northeastern corner of the lake (fig. 2). The location of each sample, expressed in latitude and longitude, is given in appendix 1, along with water depth, grid location, and laboratory analysis number. Grab samples were obtained from 286 of the 303 sampling stations in the grid network. At the remaining 17 stations, coarse lag gravels or bedrock hindered or completely prevented recovery of samples.

The surficial lake bottom samples were taken using a Shipek grab sampler (Hydroproducts Ltd., San Diego). Trials of grab samplers, undertaken by the Canada Centre of Inland Waters, demonstrated the ability of the Shipek to take relatively undisturbed samples of most of the surface-sediment types occurring in the Great Lakes (Sly, 1969). Gross et al. (1970) described the operation of the Shipek sampler in southern Lake Michigan as it was used by the Illinois State Geological Survey. Satisfactory samples were recovered, except for those in areas of bedrock outcrop or large boulder accumulations. After recovery of each sample, the surface layers were observed. If necessary, other samples were taken until an undisturbed sample had been obtained. To insure horizontal orientations of the top sediment layers, sample buckets were taken to the shipboard laboratory and placed in a stand before being examined.

The hydrogen ion activities (pH) and the oxidation-reduction potentials (Eh) of the samples were measured with a Metrohm E-208A pH meter, using a combination of glass/AgCl and platinum/AgCl electrodes. The electrodes were placed in clamps supported by a stand over the sample bucket. They were then inserted into the sediment to a depth of 1.5 cm, and the sediment temperature was recorded immediately. The pH measurements were taken between 30 and 60 sec after insertion. The values did not drift after this amount of time, indicating that the samples were well buffered. The Eh was measured after 10 min when drift, which had initially been rapid, had either ceased or was very slow, indicating that equilibrium or quasi-equilibrium had been established.

To ensure uniform subsampling of the sediment in the Shipek bucket, a box subsampler constructed of stainless steel (5 cm square by 3 cm deep and capable of retaining 75 ml of sediment) was used. The subsampler was pressed gently into the sediment in the Shipek bucket and a slide was eased into horizontal slots cut in the subsampler, which was then positioned to obtain an undisturbed sample of the top 3 cm of sediment.

Two subsamples were bagged and frozen for geochemical analysis, and two were bagged and stored at 40°C for sedimentologic analysis. One additional subsample was made and saved as a spare. Detailed sediment descriptions—including depth, position, and color—were made on one bucket, and the homogeneity was noted for all buckets. This was the same procedure followed by Thomas, Kemp, and Lewis (1972, 1973); Thomas et al. (1976); and Thomas and Jaquet (1975) in the other Great Lakes.

Ship navigation used a Decca 416 radar unit with a variable range marker. Fixes were obtained at arrival and departure from each sampling station and at 15-minute intervals between stations (fig. 2). The distances between the ship and two or more identifiable shorelines, docks, or major inland landmarks were determined by using the variable range marker. Locations were then plotted on the navigation chart and recorded as longitude and latitude. The recorded positions are accurate to within about 500 m in the center of the lake, and are more accurate in nearshore areas.

Continuous profiles were made by a Kelvin Hughes MS26B echosounder operating at 14.25 kHz. The echosounder provided accurate records in areas underlain by lacustrine sediment, whereas in areas underlain by coarse gravel, till, or bedrock, there was little or no acoustical penetration. Because Silver and Lineback(1972) determined the velocity of sound in lacustrine sediments cored from southern Lake Michigan to be within 10 percent of the velocity of sound in water, a uniform vertical scale was used in interpreting the profiles. Maximum acoustical penetration of the lake bottom was 35 m.

Wickham et al. (1978) have interpreted the 5,140 km of profiles obtained from this cruise in 1975 and the 3,000 km of profiles previously obtained in 1970, 1971, and 1972. In their report, the distributions of several glaciolacustrine and lacustrine stratigraphic units were mapped and related to sediment sources and to the glacial history of the lake.

Particle size analysis

The unit of grain size used throughout his report is based on the Phi (ϕ) scale. The scale is based on negative log-

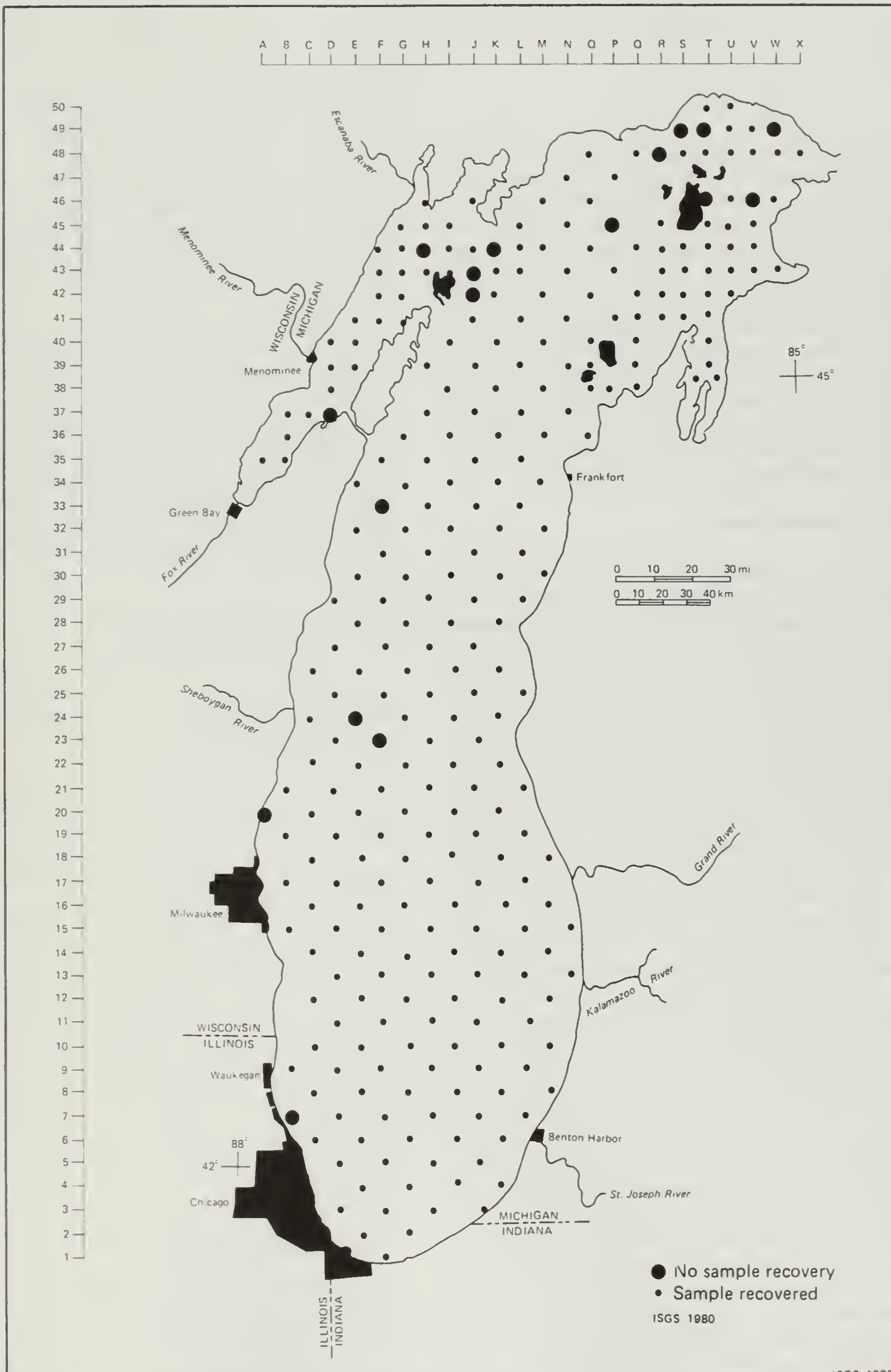

Figure 2. Sample location grid for Lake Michigan.

arithms to base 2 and is related to a millimeter scale as follows:

$$\phi = -\text{Log}_2 \text{ size (mm)}$$

The wet samples were sieved through a 4-ϕ screen. The material coarser than 4 ϕ was dried and sieved at 0.5-ϕ intervals from -4 to +4 ϕ. The material finer than 4 ϕ was analyzed by standard pipette techniques (Krumbein and Pettijohn, 1938) at 1.0-ϕ intervals from 4 to 9 ϕ, after dispersing the sediment in a 0.5 percent wt/vol Calgon solution and homogenizing for 15 min with an electric mixer. For a few samples high in clay and organic matter, a 1 percent Calgon concentration was required for particle dispersion. All size classes were then combined, and moment measures were calculated for mean grain size, standard deviation, skewness, and kurtosis after the method of Krumbein and Pettijohn (1938), and using a computer program developed by Coakley and Beal (1969).

Methods of chemical analysis

The methods of chemical analysis used in this study to determine element concentrations in Lake Michigan sediments are summarized in table 1. The CCIW prepared all samples for chemical analysis by freeze drying, sieving through a 20-mesh screen to remove shell and animal fragments, pulverizing, and finally homogenizing the samples. Sample splits were analyzed by the CCIW and the ISGS analytical chemistry sections. Details of the methods of analysis used by the CCIW can be found in Mudroch (1977), Agemian and Chau (1976) and Capobianco (1974). The x-ray fluorescence (XRF) and optical emission spectrochemical procedures (OEP) used by the ISGS are summarized in Shimp, Leland, and White (1970); the instrumental neutron activation analysis (INAA) procedures are summarized in Kothandaraman et al. (1977).

As noted in table 1, there are two or more independent analyses for 23 of the elements, done either by different methods or in different laboratories. Judgments had to be made in each instance as to whether these analyses were equally reliable and should be averaged, or whether one or more were preferable. Figures 3 to 8 are scatter plots of zinc by INAA and AA (atomic absorption analysis), chromium by INAA and AA, sodium by INAA and XRF, lead by AA and OEP, arsenic by INAA and AA, and mercury by AA and NAA-RC. The results for zinc, lead, mercury, and arsenic show fairly good agreement among the methods, but there are significant inconsistencies in the results for chromium and sodium. Because only 93 samples were analyzed by optical emission spectroscopy, results obtained by this method were generally used only for checking the reasonableness of data obtained by other methods. These results, however, are the only values for Be, V, and Zr.

INAA data are preferred for Na, Ag, As, Co, Cr, Mo, and Se, even though the results for Ag, Mo, and Se are uncertain and are not included in the statistical treatment of the results. INAA results for Ba, Lu, Sb, Sr, Tb, U, and W had a relative error of ± 25 percent because of poorer counting statistics and interferences. AA results are preferred for Cu, Ni, Pb, and Zn, largely because of this method's greater sensitivity. The results reported for mercury are an average of AA and NAA-RC values, if both were available. Those AA results for mercury that seemed high were checked by NAA-RC; these data are compared in figure 8. X-ray fluorescence results for major and minor elements are from the ISGS, except for the Mn results, which are from the CCIW.

One accepted method to check the validity of analytical procedures is to analyze standard reference materials. At the time of this project, no reference samples from the National Bureau of Standards were available with a matrix comparable to that of the recent sediments of Lake Michigan. The Illinois State Geological Survey participated in the analysis of the International Atomic Energy Agency Round Robin Soil-5. The values determined in the analysis can be used to evaluate the accuracy and precision of specific ISGS methods. For most elements the results are quite

TABLE 1. Methods used to determine trace, minor, and major element concentrations

Element	Method(s)
Ba, Br, Ce, Cs, Eu, Ga, Hf, La, Lu, Rb, Sb, Sc, Sm, Sr, Ta, Tb, Th, U, W, Yb	INAA
Fe, K, Na	INAA, XRF, XRF[a]
Mn	OEP, XRF[a], INAA
Ag, Co, Mo	INAA, OEP
Cr, Ni, Zn	INAA, OEP, AA[a]
Al, Ca, Cl, P, Si, Ti, Mg, S	XRF, XRF[a]
Pb, Cu	OEP, AA[a]
Be, V, Zr	OEP
As, Se	INAA, AA[a]
Hg	NAA-RC, AA[a]
Cd	AA[a]
Total organic carbon	Leco[a]

[a] Analysis performed by CCIW.

INAA = Instrumental neutron activation analysis.
XRF = X-ray fluorescence analysis.
OEP = Optical emission spectrochemical analysis, photographic.
AA = Atomic absorption analysis.
NAA-RC = Neutron activation analysis with radiochemical separation.
Leco = Induction furnace carbon analyzer.

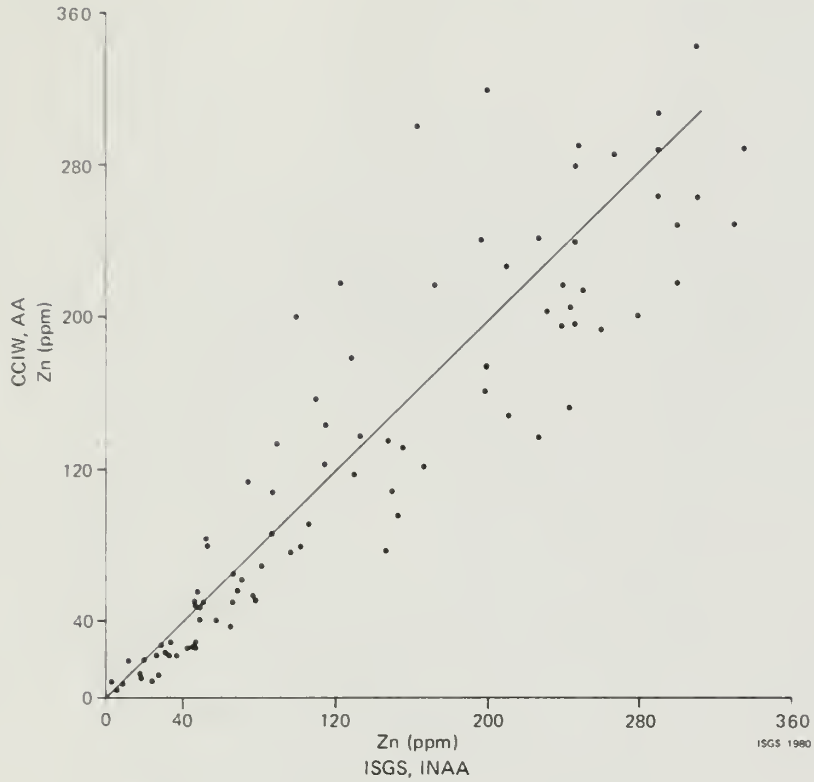

Figure 3. Zinc comparison; CCIW, AA vs ISGS, INAA.

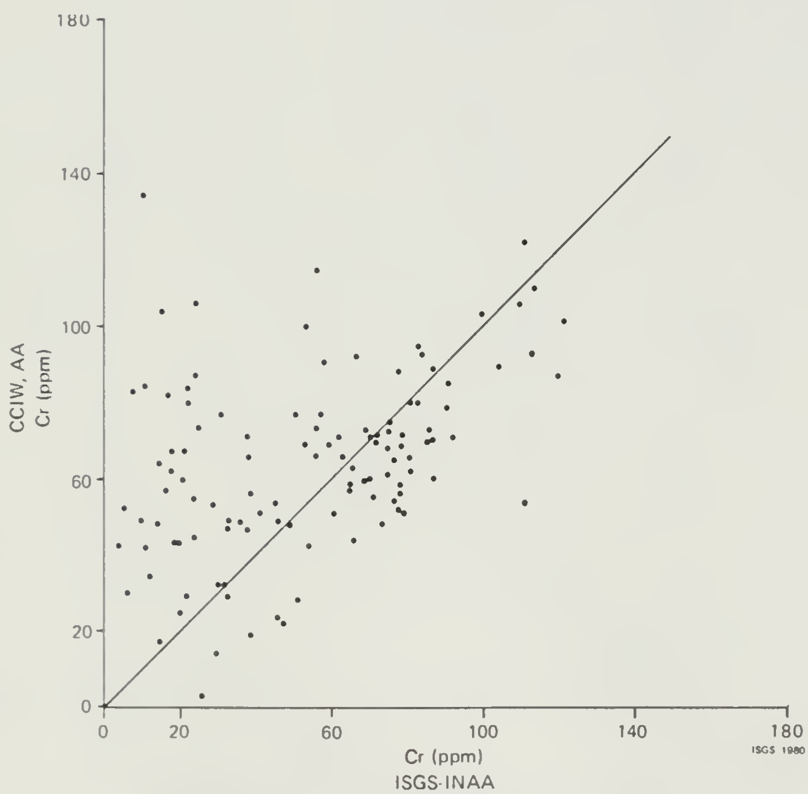

Figure 4. Chromium comparison; CCIW, AA vs ISGS, INAA.

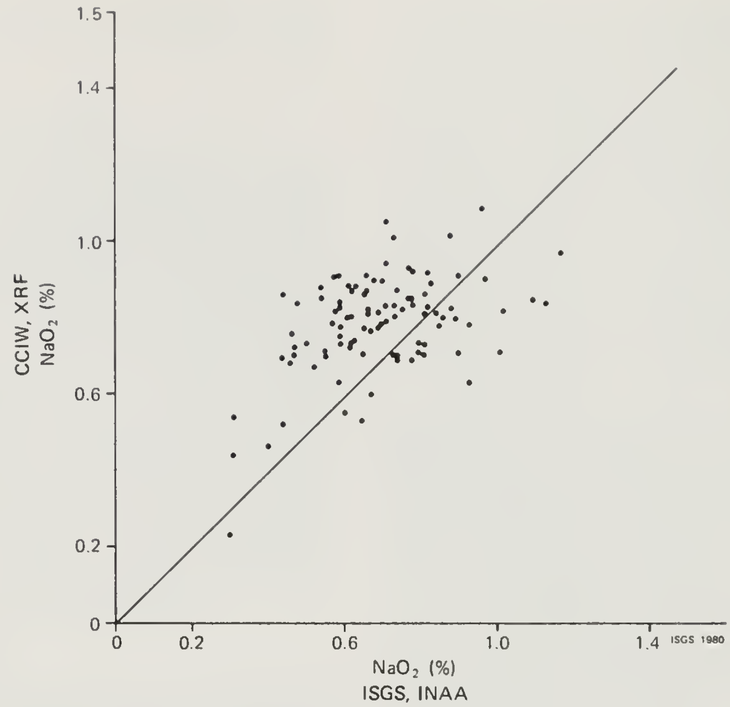

Figure 5. Sodium comparison; CCIW, XRF vs ISGS, INAA.

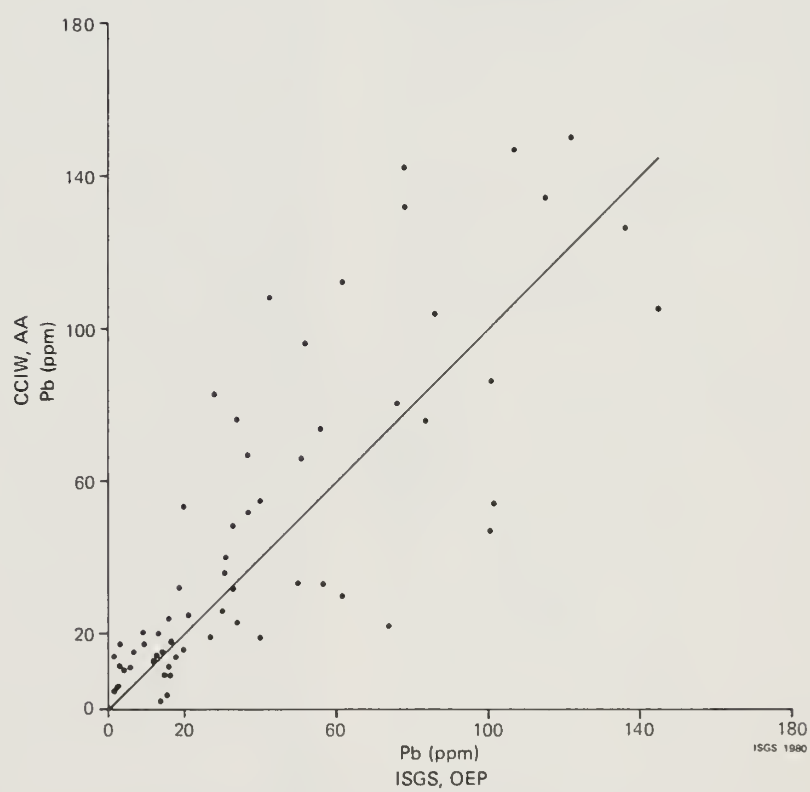

Figure 6. Lead comparison; CCIW, AA vs ISGS, OEP.

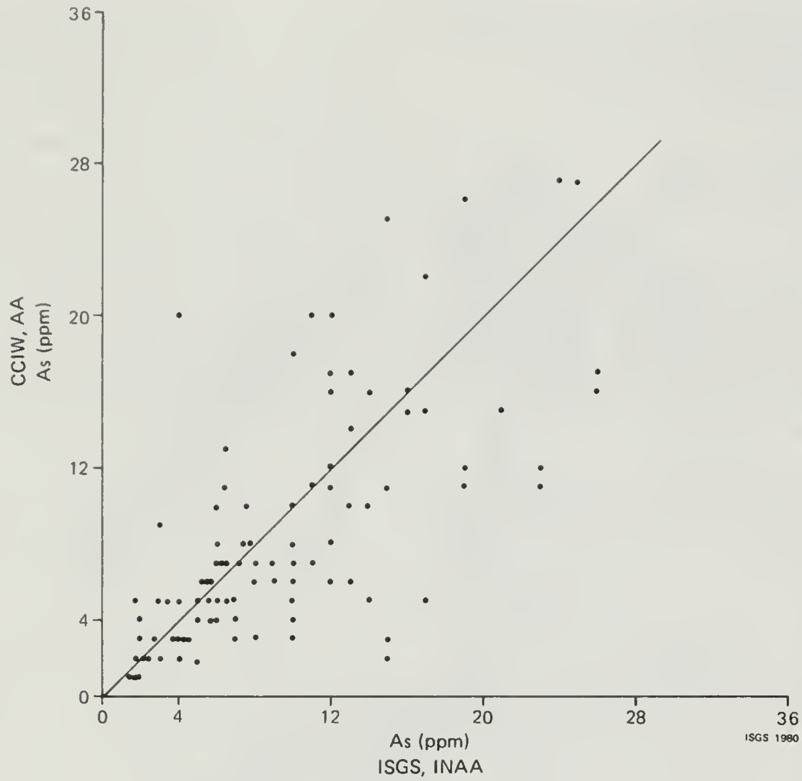

Figure 7. Arsenic comparison; CCIW, AA vs ISGS, INAA.

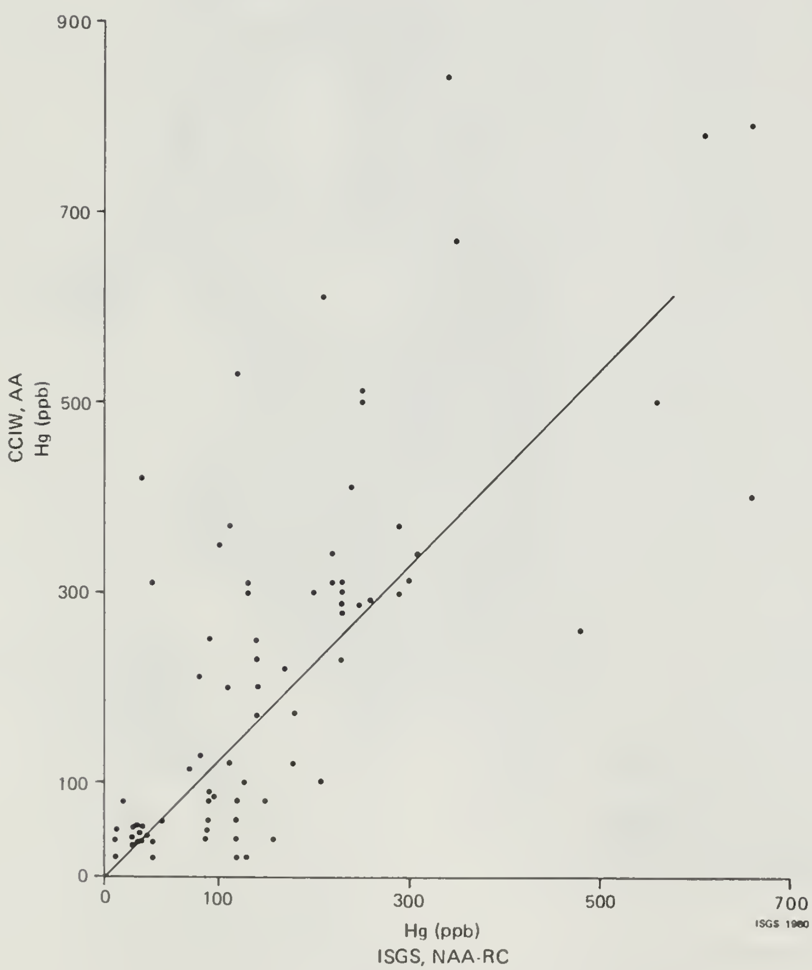

Figure 8. Mercury comparison; CCIW, AA vs ISGS, NAA-RC.

good (tables 2, 3a, and 3b). Discrepancies may arise partly from the nature of the samples and from the nature of many of the reference values cited in the literature.

RESULTS AND DISCUSSION

Grain size measurements

The results of the grain size analyses are tabulated in appendix 2. These results include mean grain size and standard deviation expressed in ϕ units; percentages of sand-, silt-, and clay-sized fractions; skewness; kurtosis; Eh; and pH of the sample.

The areal distribution of bottom types in Lake Michigan, based on the field descriptions and seismic profiles taken on the 1975 cruise, has been plotted by Thomas (unpublished map) and is shown in figure 9. The entire nearshore area is composed of glacial tills, bedrock, or sand, with an area of hard bottom off the Milwaukee-Racine shore. Glaciolacustrine clays tend to occur between the nearshore sand or till regions and in the postglacial muds that occur in the deeper basins. Type A mud is defined as a continuous deposit of postglacial mud. Type B muds are thinner postglacial muds that occur most frequently in depressions on the lake floor, but in some cases may cover bottom rises; type B muds cover 50 percent of the lake bottom. Areas of type A mud are regions of current sedimentation.

TABLE 2. Values obtained by instrumental neutron activation analysis for I.A.E.A. Soil-5

Element	This study ppm	No.[a]	Reference value[b] ppm
Fe	4.92 ± 1.01[c]	27	4.45 ± .19[c]
K	1.66 ± .34[c]	27	1.86 ± .15[c]
Na	1.87 ± .29[c]	27	1.92 ± .11[c]
Ag	2.6 ± .8	24	(1.9)[d]
As	97 ± 11	27	93.9 ± 7.5
Ba	727 ± 117	25	561 ± 53
Br	6 ± 2	25	5.4 ± 1
Ce	79 ± 24	27	59.7 ± 3
Co	20 ± 7	27	14.8 ± .8
Cr	34 ± 6	27	28.9 ± 2.8
Cs	81 ± 14	27	56.7 ± 3.3
Eu	1.7 ± .3	27	1.18 ± .08
Ga	17 ± 4	27	18.4 ± 1.6
Hf	10 ± 2	27	6.3 ± .3
La	31 ± 5	27	28 ± 1.5
Lu	0.5 ± .1	24	0.34 ± .04
Mo			(1.7)
Ni	14 ± 6	10	(13)
Rb	188 ± 51	27	138 ± 7.4
Sb	26 ± 8	27	14 ± 2.2
Sc	18 ± 2	27	14.8 ± .7
Se	1.7 ± .6	25	(1.4)
Sm	5.6 ± .8	27	5.4 ± .4
Sr	375 ± 100	27	(330)
Ta	0.96 ± .17	27	0.76 ± .06
Tb	1.1 ± 0.6	27	0.66 ± .07
Th	15 ± 3	27	11.3 ± .7
U	3 ± 1.3	15	3.0 ± .5
W	5 ± 1.2	23	(5)
Yb	2.9 ± .7	27	2.2 ± .2
Zn	427 ± 86	27	368 ± 8

[a] No. = Number of determinations
[b] Report on the intercomparison run Soil-5, IAEA/RL/46, January 1978.
[c] Values in percent.
[d] Parentheses indicate informative values only.

TABLE 3a. Values obtained by optical emission spectrochemical analysis, photographic, for I.A.E.A. Soil-5

Element	This study (ppm)	No.[a]	Reference value[b] (ppm)
Mn	746 ± 150	7	852 ± 37
Ag	1.1 ± .2	7	(1.9)[c]
Be	1.8 ± .04	7	1.77 ± .27
Co	12 ± 1.4	7	14.8 ± .8
Cr	25 ± 3	7	28.9 ± 2.8
Cu	50 ± 5	7	77 ± 4.7
Mo	5.9 ± .9	7	(1.7)
Ni	8.4 ± 2.2	7	(13)
Pb	116 ± 24	7	129 ± 26
V	134 ± 13	7	(151)
Zn	350 ± 29	7	368 ± 8
Zr	178 ± 27	7	(221)

[a] No. = Number of samples.
[b] Report on the intercomparison run Soil-5, IAEA/RL/46, January 1978.
[c] Parentheses indicate informative values only.

TABLE 3b. Values obtained by x-ray fluorescence analysis for I.A.E.A. Soil-5

Element	This study (%)	Reference value[a] (%)
Si	27.6 ± .14	(33)[b]
Al	8.52 ± .09	8.19 ± .28
Fe	4.74 ± .05	4.45 ± .19
Mg	0.61 ± .02	(1.5)
Ca	1.63 ± .02	(2.2)
Na	1.71 ± .10	1.92 ± .11
K	1.84 ± .02	1.86 ± .15
Ti	0.52 ± .003	(0.47)
P	0.104 ± .01	(0.11)
Mn	0.10 ± .01	0.08 ± 0.004

[a] Report on the intercomparison run Soil-5, IAEA/RL/46, January 1978.
[b] Parentheses indicate informative values only.

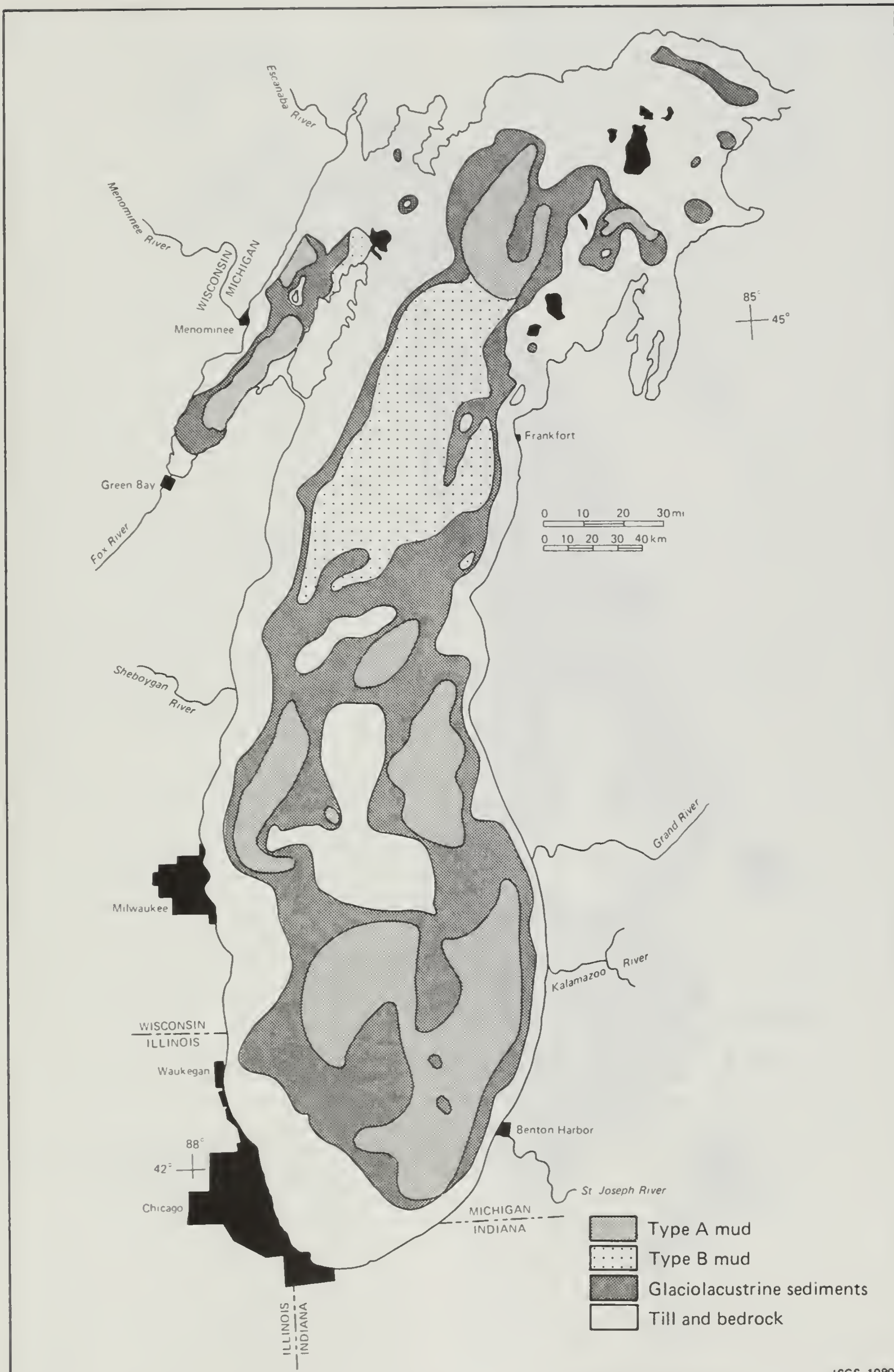

Figure 9. Distribution of bottom sediments in Lake Michigan.

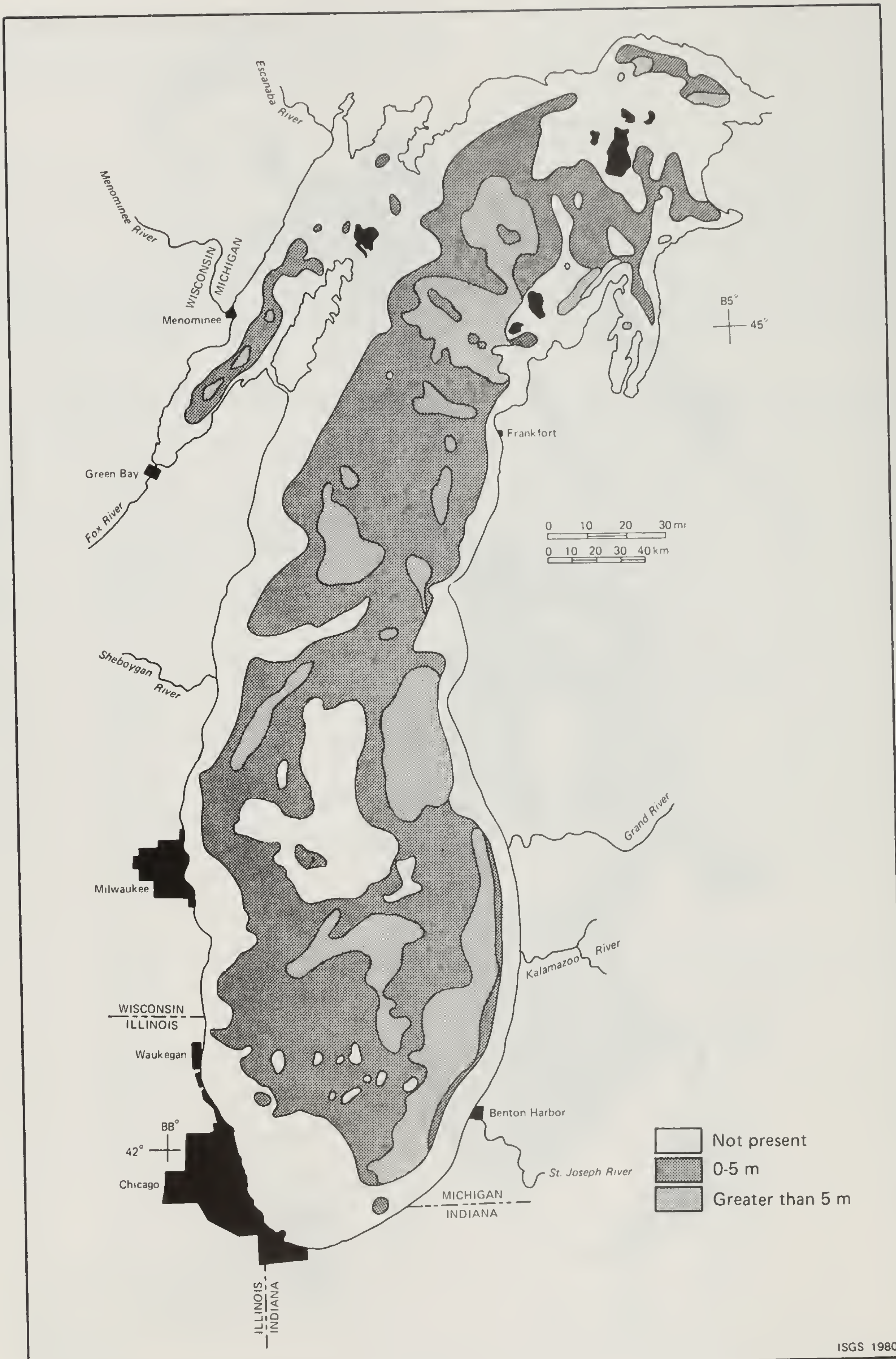

Figure 10. Thickness of gray clay (after Wickham, 1978).

When figure 9 (bottom sediment distribution) is compared to figure 10 (thickness of the gray clay, from Wickham et al., 1978), similar patterns of sediment distribution are apparent—for instance, areas of thicker deposits of the gray clay unit correspond roughly with the areas of type A mud accumulation. These areas of thick deposits, located mainly along the eastern side of the lake, are the result of postglacial sediments being carried into the lake by the rivers of western Michigan.

The sediment size distribution observed in the upper 3 cm of the sediments can be displayed by several different techniques. Figure 11 is a histogram plot of the frequency of mean grain sizes based on units. From this plot, it is apparent that there are two distinct sediment types—a sand-sized fraction with a mean grain size of about 3 ϕ, and a clay-sized fraction with a mean size of about 8 ϕ.

The areal variation of mean grain size is shown in figure 12. This distribution is similar to that yielded by the bottom sediment analysis shown in figure 9. Coarse to fine sands are found along the shore around the entire lake and in an area near the Mid-lake High. Very fine silts and clay-sized sediments are found in the deeper portions of the northern and southern basins and in a number of isolated small depressions in the northern straits area. The coarse to fine silt-sized fraction tends to occur as a transition zone between sand- and clay-sized sediments.

The areal distribution of clay-sized sediments is shown in figure 13. This distribution is also similar to that shown in figure 9. The higher percentages of clay-sized material in the deeper parts of the northern basin correspond to what was shown in figure 12.

The frequency of the various sediment types, as defined by Shepard's classification (1954), is shown as a triangular diagram in figure 14. This same classification was used by Thomas, Kemp, and Lewis (1972, 1973), and Thomas et al. (1976) in the other Great Lakes. Figure 14 demonstrates the bimodal character of the sediments, which are mostly silty-clay and sand. The generalized areal distribution of textural types is shown in figure 15. For clarity, only the sand, silty-clay, clayey-silt, and sand-silt-clay types are plotted separately, the clayey-sand and silty-sand types having been combined. Only 10 samples did not fit into one of these types; each of these was assigned to the type to which it was most similar. Figure 15 compares well with figures 9, 12, and 13. Clayey-silt is found on the eastern side of the lake, where there is more input from rivers. The steepness of the lake floor along the east side of the northern basin explains the change from fine-grained samples to sands.

In figure 16, the relationship between mean grain size (ϕ) and depth in meters is plotted, and nearshore, nondepositional areas are distinguished from the deep basin areas of sedimentation. The plot can be thought of as a measure of the physical energy of the system with respect to grain size. Generally, grain size decreases as the depositional energy decreases. The depositional energies are caused by wind-driven currents and waves. The plot in figure 16

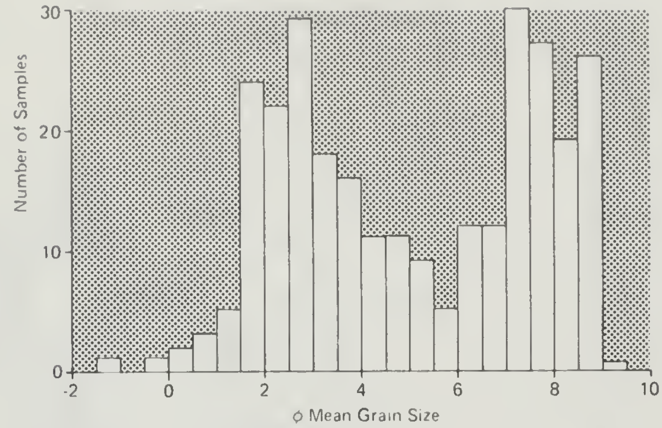

Figure 11. Mean grain size distribution in the upper 3 cm of Lake Michigan sediments.

corresponds closely to a plot made by Sly (1978) in which lacustrine and marine particle-size depth relationships are compared.

A plot of mean grain size versus standard deviation (fig. 17) is an aid to sediment sorting. The clay-sized fraction tends to be the best sorted, whereas the silt-sized materials tend to have higher standard deviation—that is, they are poorly sorted. In a study of Lake Huron, this relationship between grain size and standard deviation has been interpreted by Thomas, Kemp, and Lewis (1973) to be caused by the mixing of sand and clay. Sly (1978), however, pointed out that standard deviation is insensitive to variation in the tails of a size distribution curve, and that mean grain size may retain the same value despite a change in the mixture. The relationship shown in figure 17 is comparable to that in plots made for Lakes Erie, Ontario, and Huron by Thomas, Kemp, and Lewis (1972, 1973) and Thomas et al. (1976), except that the tail of the curve in the sand-sized range does not curve back up as in Thomas's plots. This would suggest that the sand-sized fraction in Lake Michigan is better sorted than the sand-sized fraction in Lake Huron—that is, it does not contain the admixed gravel that the fraction in Lake Huron contains.

Thomas, Kemp, and Lewis (1972, 1973) and Thomas et al. (1976) plotted skewness versus mean grain size to measure the amount of silt present in the end members of the size distributions, and found that the presence of silt gave a negative skewness to the clay-sized fraction and a positive skewness to the coarse fraction. Figure 18, a plot of this type for Lake Michigan samples, shows a pattern very similar to that which Thomas found for the other lakes.

The relationship between mean grain size and kurtosis is shown in figure 19. This type of plot has been used by Thomas, Kemp, and Lewis (1972, 1973), and Thomas et al. (1976) for Lakes Ontario, Huron, and Erie to show the relative importance of the silt component in the clayey and sandy end members of the size distribution. As shown in figure 19, the sand-sized fraction is more leptokurtic than the clay-sized fraction in Lake Michigan sediments;

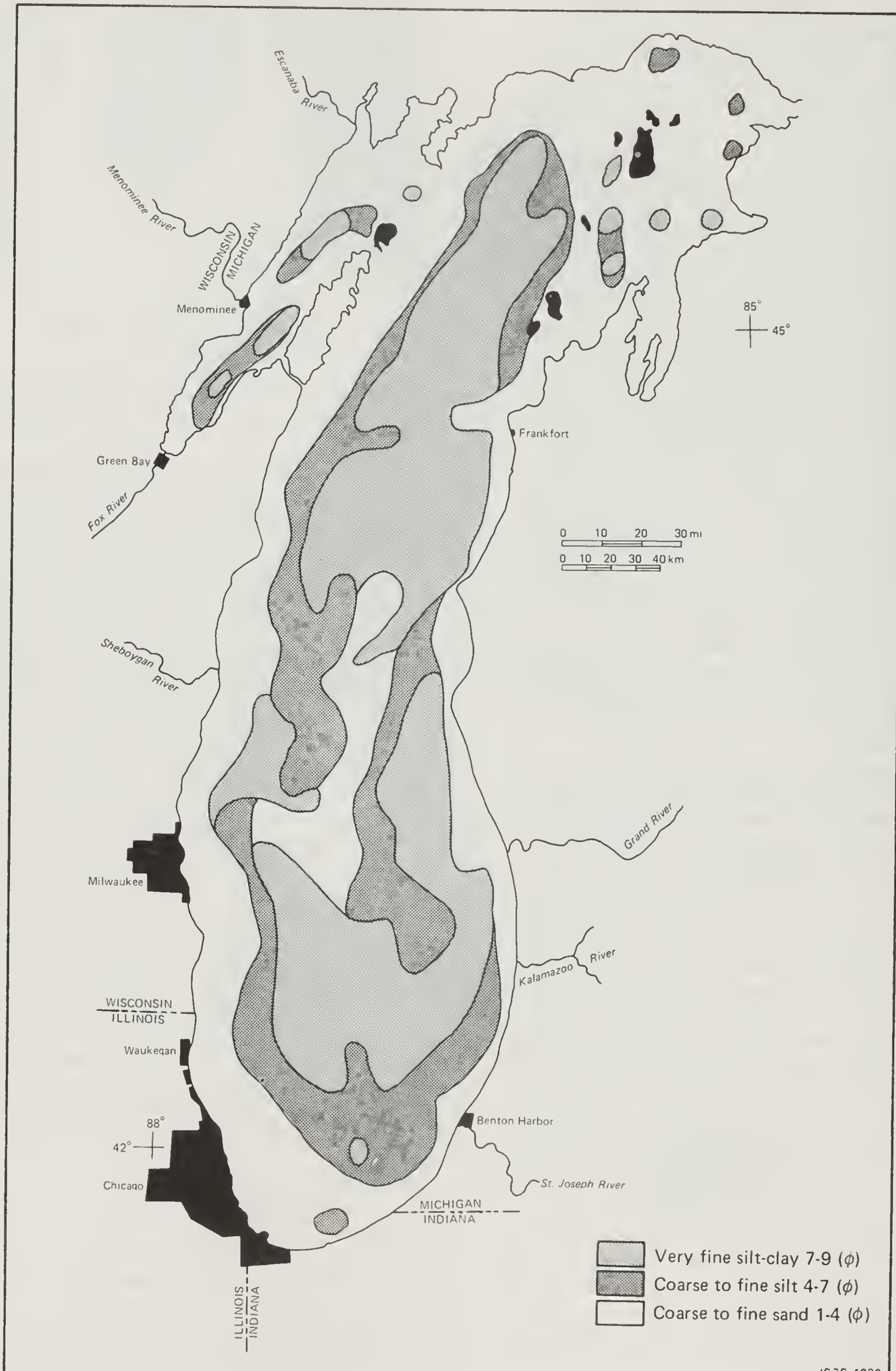

Figure 12. Mean grain size ($\emptyset$) distribution in upper 3 cm of Lake Michigan sediments.

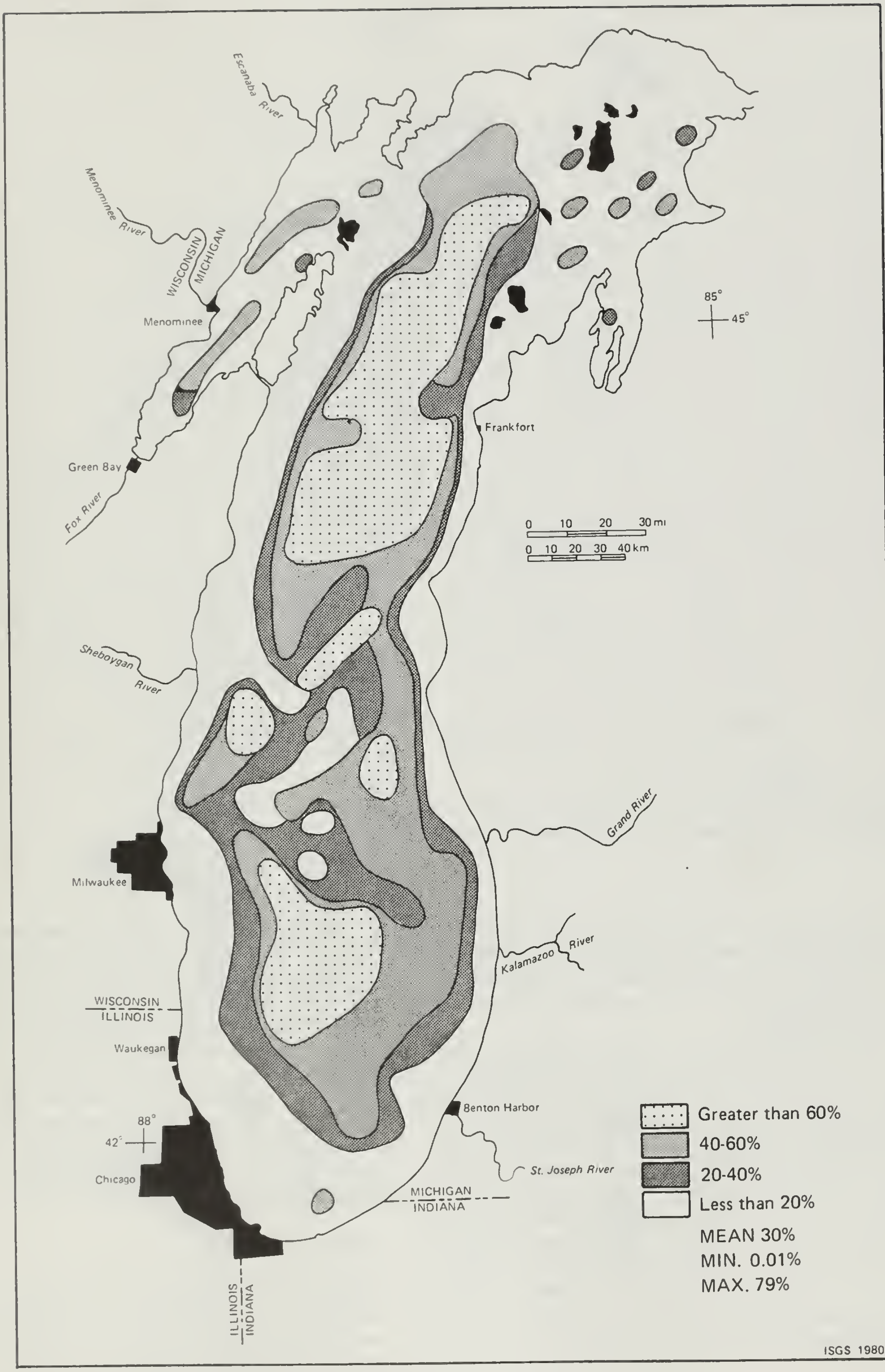

Figure 13. Clay size sediment distribution in the upper 3 cm of Lake Michigan.

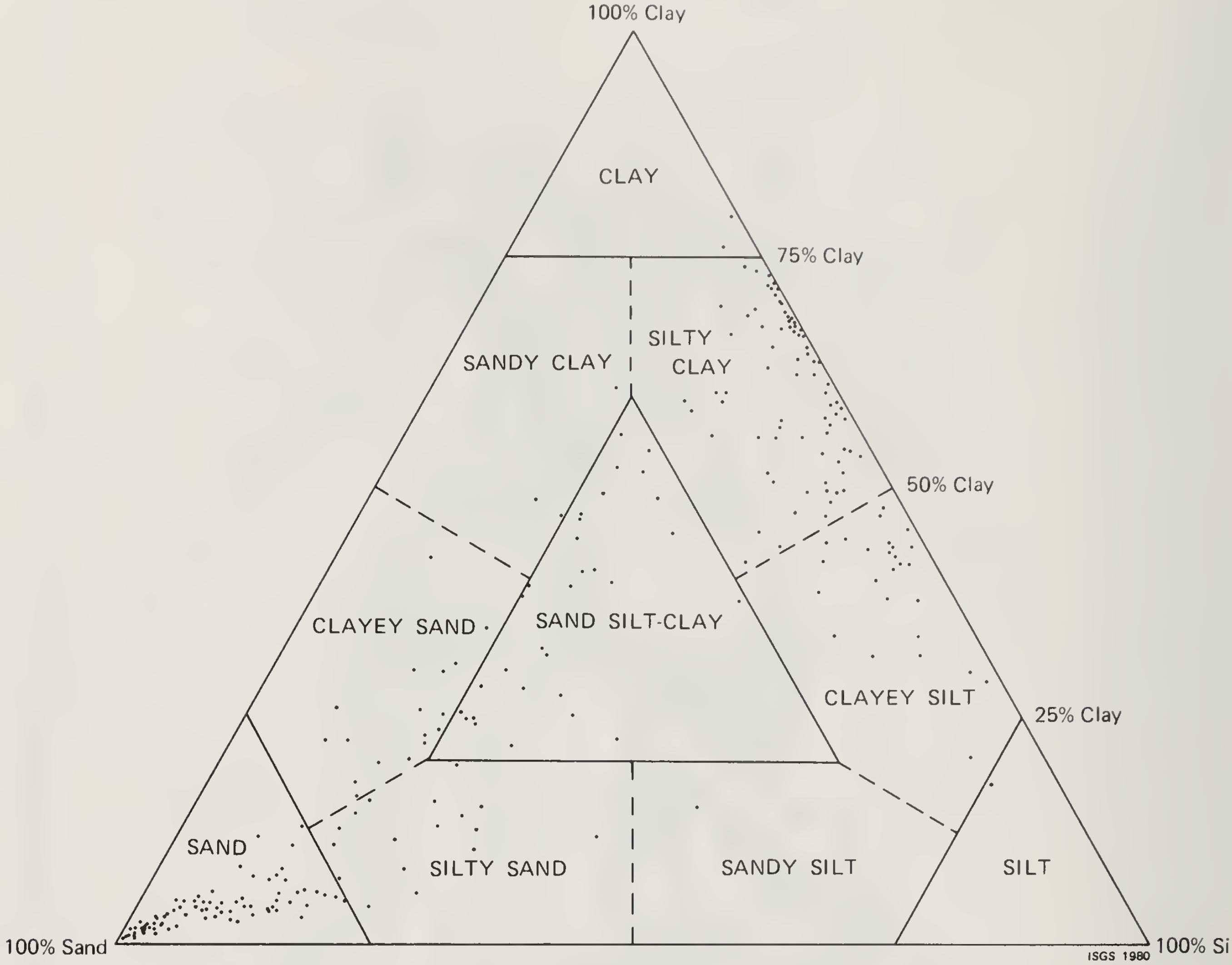

Figure 14. Textural classification of surficial sediments of Lake Michigan (after Shephard, 1954).

the size range from 4 to 8 ϕ is platykurtic. Thomas, Kemp, and Lewis (1973) traced similar differences in kurtosis in his samples to the larger percentage of silt associated with clayey sediments relative to the percentage of silt associated with sand sediments.

A plot of skewness versus kurtosis is shown in figure 20, again following the plotting method used by Thomas, Kemp, and Lewis (1972, 1973), and Thomas et al. (1976). The figure, divided into four regions by points A, B, C, and D, shows the line (obtained by inspection) that best fits to the points. The samples in region A, which has positive skewness and is leptokurtic, are sands. More sands are found in region B, which is positively skewed and platykurtic. Those samples that fall in region D, which has negative skewness and is leptokurtic, are clay rich. So are those in region C, which is platykurtic and negatively skewed. The trend line is interpreted by Thomas et al. (1976) to represent energy declining from a high-energy region A to a low-energy region D.

The similarity of values of the sedimentary parameters for Lake Michigan to the values for Lakes Erie, Ontario, and Huron is apparent when figures 17 to 20 are compared with the analogous plots in Thomas et al. (1972, 1973, 1976). Table 4 lists the ranges of mean grain size and standard deviation observed in the five Great Lakes. The range of standard deviation found for Lake Michigan samples is comparable to the ranges for the other Great Lakes (with the exception of one sample with a higher standard deviation value of 4.8). The ranges of mean grain size are also comparable; only four of the Lake Michigan samples have mean grain sizes less than 0.0 ϕ.

Sediment pH and Eh

Hydrogen ion activity (pH) in Lake Michigan sediments generally ranged from 7.0 to 8.0, although two abnormally low values occurred at locations B-21 (pH 4.5) and H-39 (pH 5.1). These two abnormally low values may have

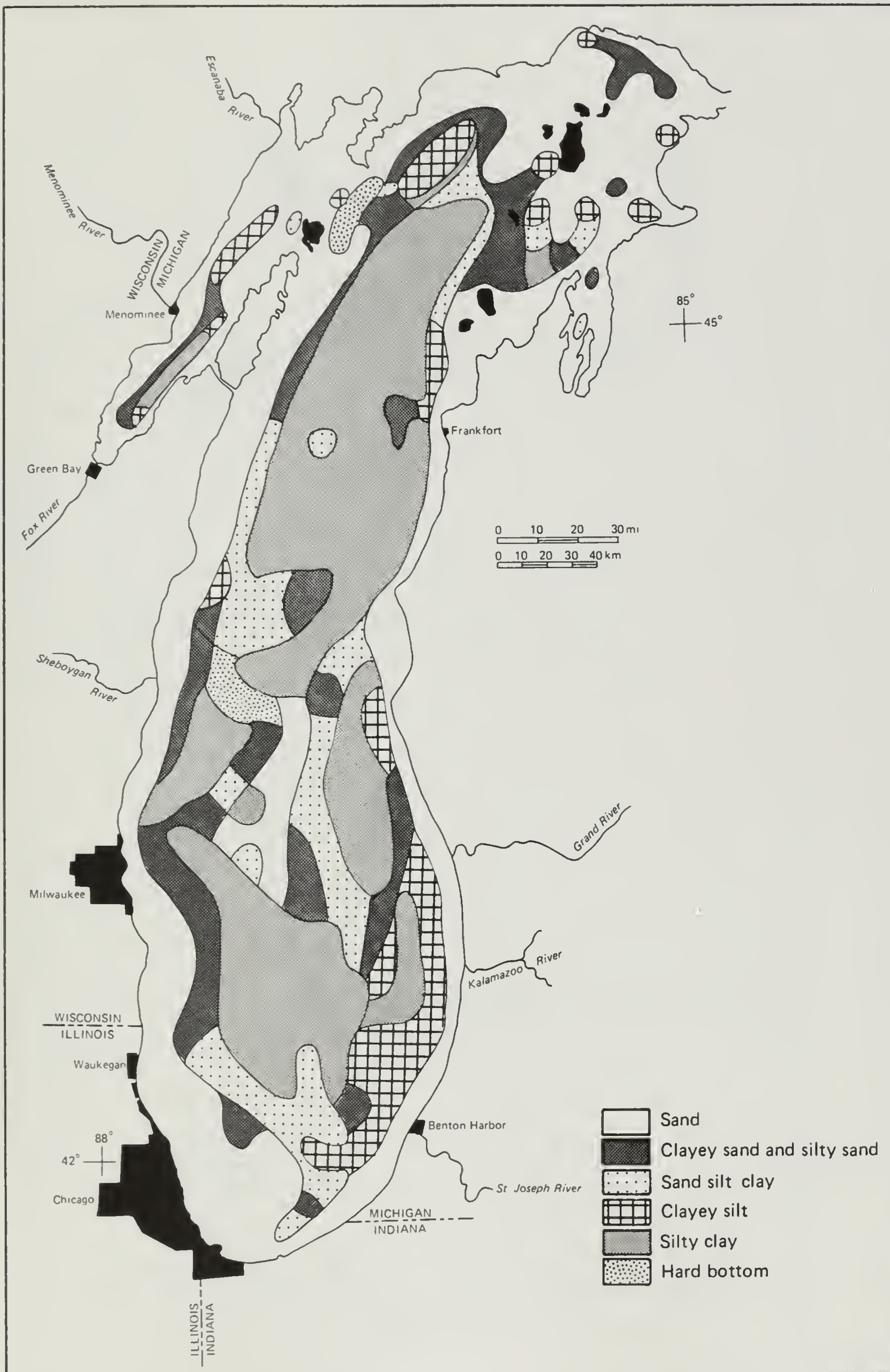

Figure 15. Generalized distribution of sediment types in the surficial sediments of Lake Michigan.

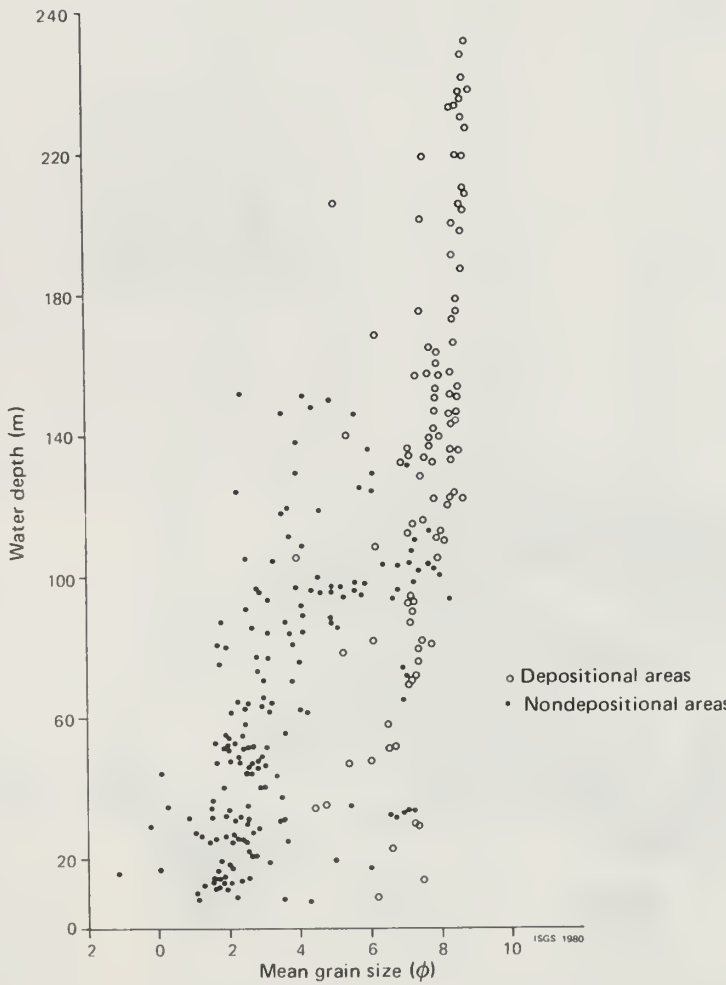

Figure 16. Relationship between mean grain size and water depth in surficial sediments of Lake Michigan.

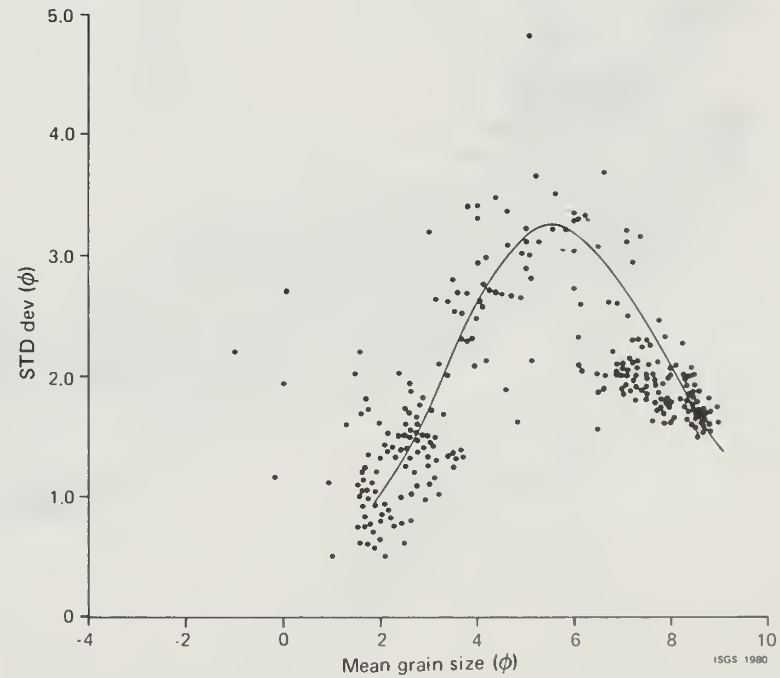

Figure 17. Relationship between mean grain size and standard deviation in surficial sediments of Lake Michigan.

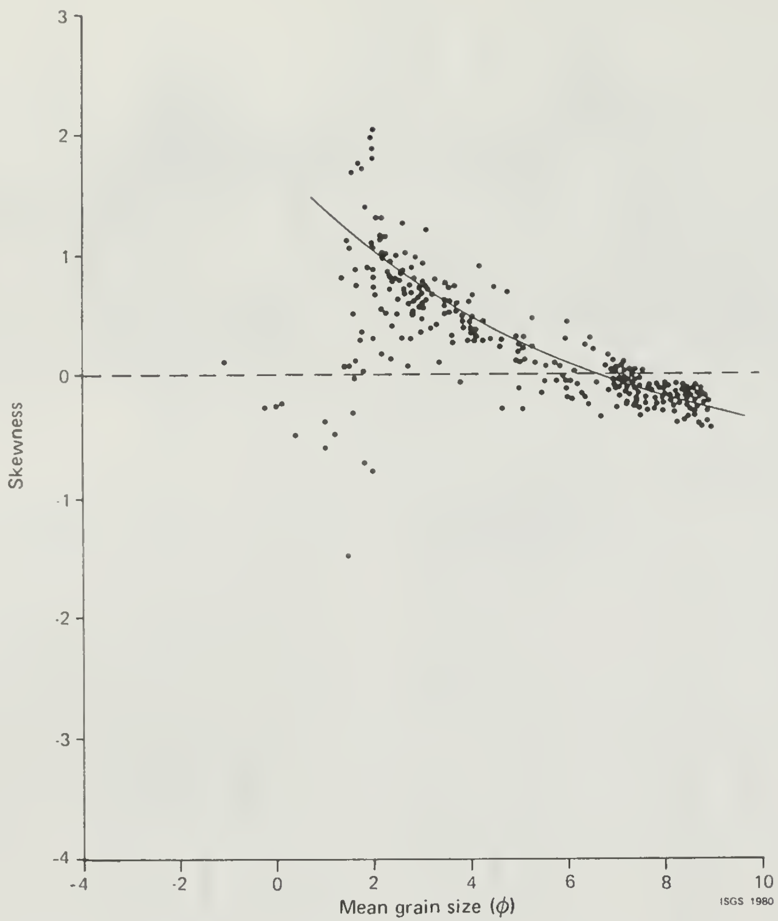

Figure 18. Relationship of mean grain size to skewness in surficial sediments of Lake Michigan.

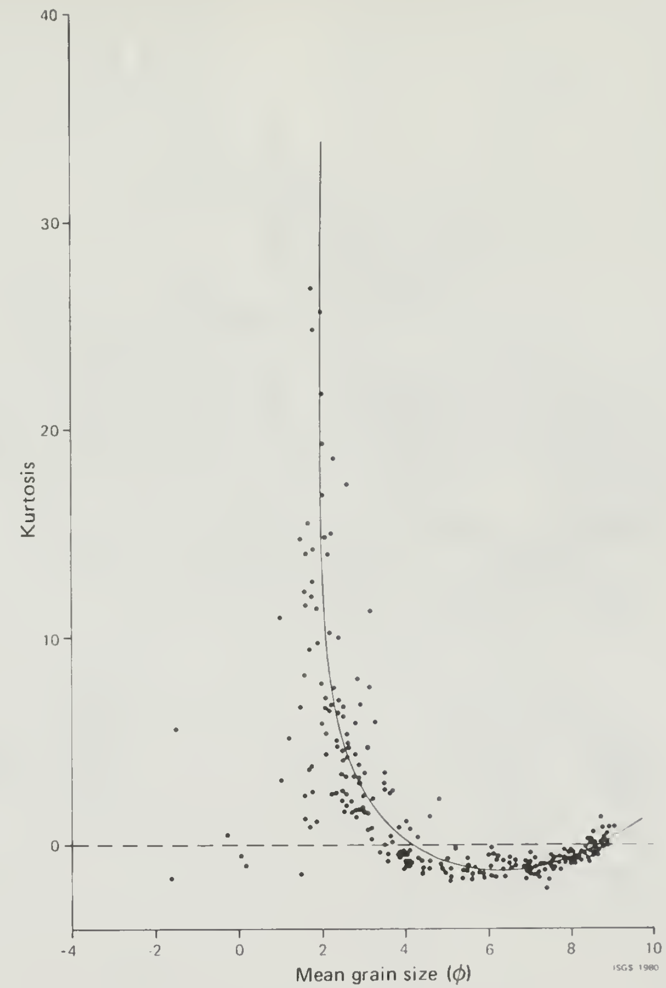

Figure 19. Relationship of mean grain size to kurtosis in surficial sediments of Lake Michigan.

Figure 20. Relationship of skewness to kurtosis in surficial sediments of Lake Michigan.

resulted in part from CO_2 produced by the decay of organic matter. The mean value of 7.6 is similar to the mean values for pH reported by Thomas, Kemp, and Lewis (1972, 1973), and Thomas et al. (1976) for Lakes Erie, Ontario, and Huron. There was no apparent areal pattern to pH values in Lake Michigan, a fact that was also noted by Torrey (1976).

The redox potential—Eh—is a measure of the state of oxidation or reduction of a system, calculated in comparison with that of a standard hydrogen electrode. Positive potentials are associated with well-oxygenated sediments, which are generally low in organic matter and can be thought of as oxidizing. Negative potentials and positive potentials less than +100 millivolts are associated with poorly oxygenated interstitial fluids or bottom waters, which are often high in organic matter and can be thought of as reducing.

The areal distribution of Eh in Lake Michigan is plotted in figure 21. The values range from -60 to +460 millivolts; the geometric mean value is +170 millivolts. The distribution shown in figure 21, comparable to that shown by Torrey (1976), is similar to the Eh range reported for Lakes Erie and Ontario by Thomas, Kemp, and Lewis (1972), and Thomas et al. (1976), and a bit lower than the value of 63 millivolts for Lake Huron (Thomas, Kemp, and Lewis, 1973). Figure 21 shows that reducing sediments (those with Eh values less than 200 millivolts) are found in areas of silty-clay and clayey-silt (fig. 15), in areas with high percentages of clay-sized particles (fig. 13), and in areas of type A or B muds (fig. 9). Lineback and Gross (1972) have shown that in the southern basin of Lake Michigan, the boundary between a gray silt facies and a brown silt facies lies along an Eh contour. The gray facies usually contains more organic matter and remains reduced partly because of microbial action. The gray color may result from the presence of reduced mineral oxides.

Classification of depositional areas

Thomas (unpublished map) divided the Great Lakes into areas in which sediment deposition is taking place, and areas of nondeposition (fig. 22). His divisions were based on physical descriptions of the samples, grain size information, and echo-sounding tracks. Using the same three criteria, a similar map was made for Lake Michigan (fig. 23), generalized to show areas of deposition that are identified in this study. Tables 5 and 6 list grid locations corresponding to the six depositional sub-basins and grid locations where little or no deposition is occurring. In the "transitional areas" (fig. 23), thin layers of recently deposited, fine-grained silty clay overlie sand or glaciolacustrine clays; these areas correspond to those in which type B muds occur (fig. 9).

Comparing figure 23 with figure 22 reveals some differences in the number and extent of the depositional sub-basins. The southern basin is defined in this report as a single basin (partly because of the uniformity of the trace element data), whereas Thomas defines it as two separate sub-basins. The northern basin as defined here includes the Sarian and Algoma Basins cited by Thomas. The Green Bay depositional area extends farther north

TABLE 4. Grain size parameters for sediments from the Great Lakes

	Range of mean grain size (ϕ)	Range of standard deviation (ϕ)
Lake Michigan[a]	-1.08-9	0.5-4.8
Lake Erie[b]	1.5-9	0.6-2.6
Lake Huron[c]	1.2-9.5	0.3-3.3
Lake Ontario[d]	1.5-9.5	0.3-2.7
Lake Superior[e]	0.5-10.0	0.6-2.7

[a] This study
[b] Thomas et al., 1976
[c] Thomas, Kemp, and Lewis, 1973
[d] Thomas, Kemp, and Lewis, 1972
[e] Thomas and Jaquet, 1975

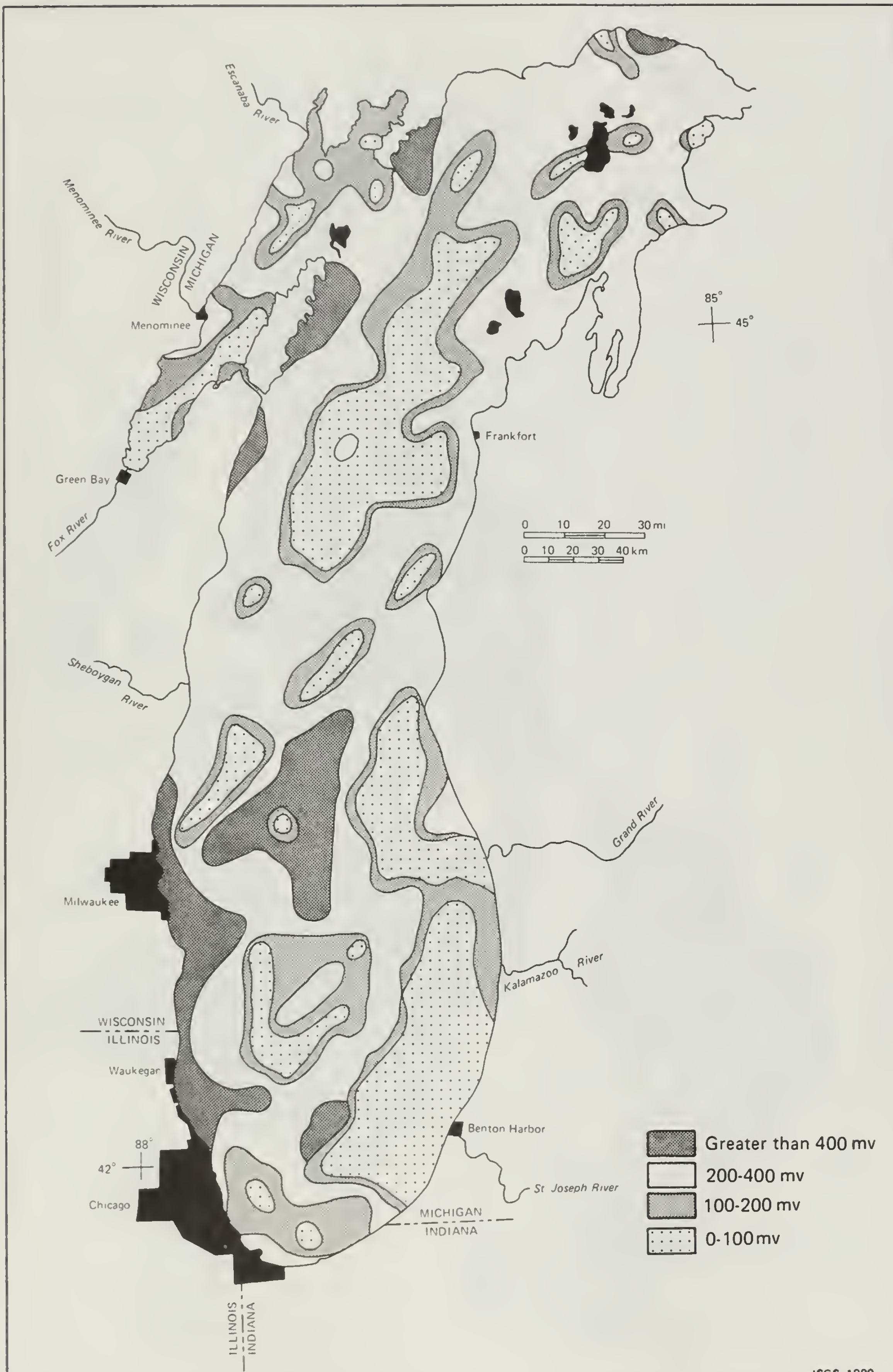

Figure 21. Eh distribution in the upper 3 cm of Lake Michigan sediments.

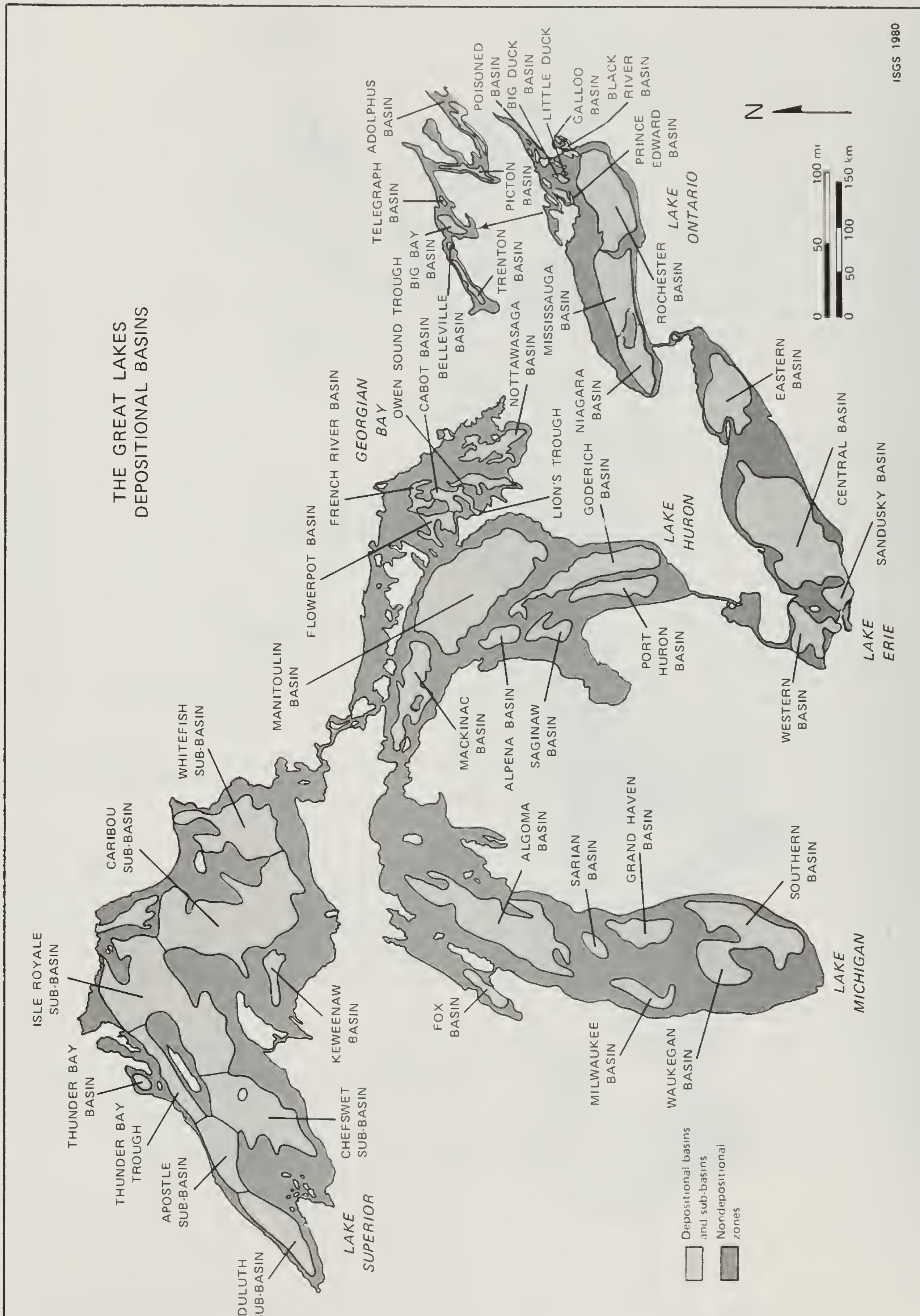

Figure 22. The great lakes depositional basins.

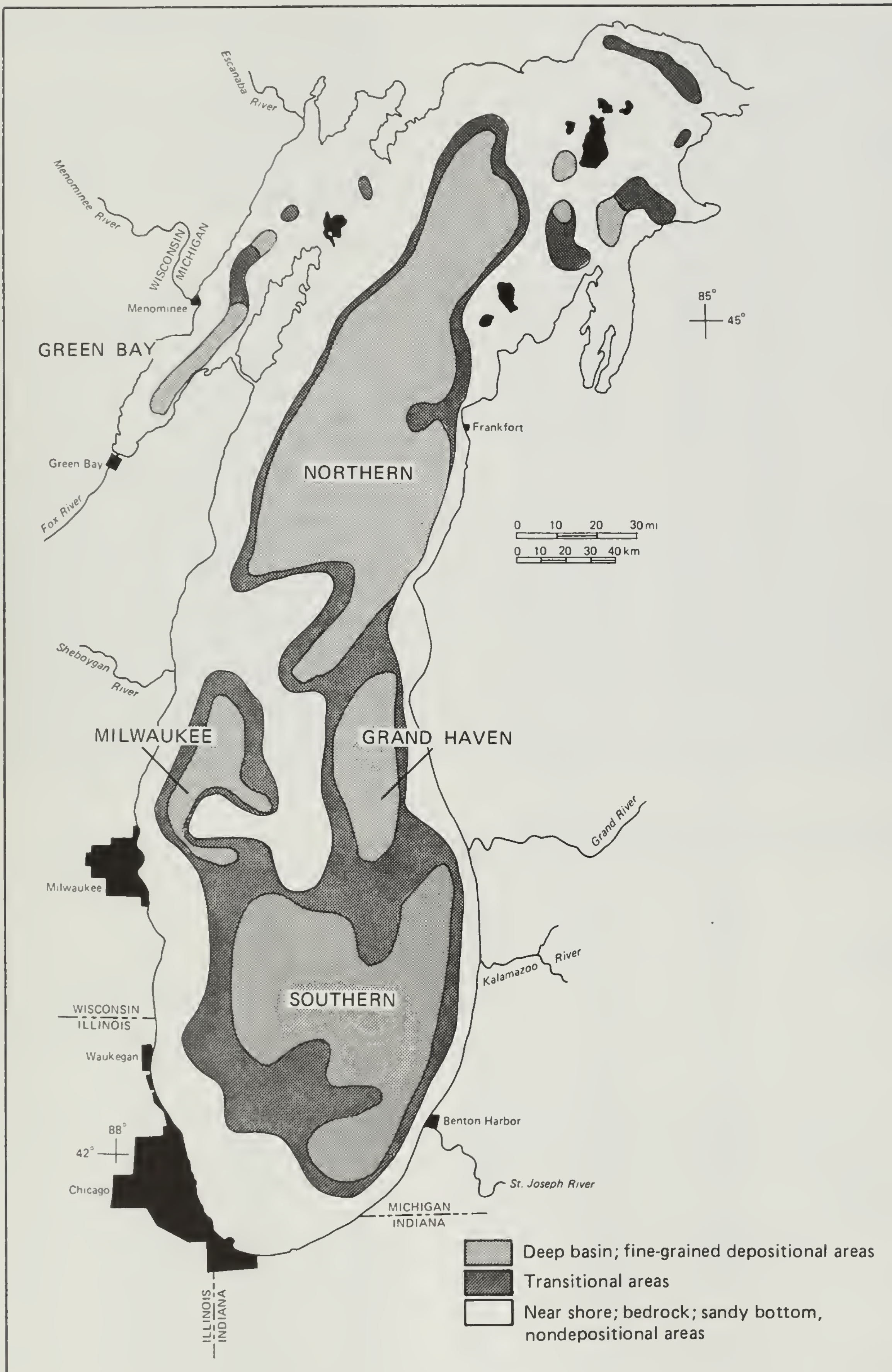

Figure 23. Generalized depositional environments of Lake Michigan.

TABLE 5. Depositional sub-basins in Lake Michigan

Sub-basins	Sample locations[a]				
	E-10	E-12	E-14	F-9	F-11
	F-13	F-15	G-10	G-12	G-14
Southern (34)	H-5	H-11	H-13	I-4	I-6
	I-8	I-10	I-12	I-14	J-5
	J-9	J-11	K-6	K-8	K-10
	K-12	L-9	L-11	L-13	L-15
	M-10	M-12	M-14	M-16	
	F-29	F-31	G-24	G-30	G-32
	G-34	H-25	H-29	H-31	H-33
	H-35	I-26	I-30	I-32	I-34
	I-36	I-38	J-27	J-29	J-31
	J-33	J-35	J-37	J-39	K-28
Northern (51)	K-30	K-32	K-34	K-36	K-38
	K-40	L-29	L-31	L-33	L-37
	L-39	L-41	M-32	M-34	M-36
	M-38	M-40	M-42	M-44	N-41
	N-43	N-45	O-42	O-44	O-46
	P-43				
Milwaukee (7)	B-19	C-20	D-17	D-21	D-23
	E-22	F-19			
Grand Haven (10)	I-20	I-22	J-17	J-19	J-21
	J-23	K-18	K-20	K-22	K-24
Green Bay (8)	B-35	B-36	C-37	D-38	E-39
	F-42	G-43	H-43		
Northern Straits (5)	R-43	R-45	T-42	T-43	W-46

[a] Refer to appendix 1 for explanation of sample locations.

than shown by Thomas for the Fox Basin, and the small isolated depressions in the straits area are identified here as depositional areas.

It should be noted that a thin cover of recent sediment with associated high levels of trace element loadings does not alone constitute a depositional basin. Resuspension of this thin layer of recent sediment by large storms could sweep an area clean and remove this most recent record.

Chemical results

The compilation of chemical analyses of 48 major, minor, and trace elements in 286 samples can be found in appendix 2. Inorganic carbon is recorded as the percentage of carbon dioxide. Appendix 2 has a "Total" column that is a sum mation of all the major and minor elements expressed as oxides. With few exceptions, the summations account for more than 90 percent of the sample, indicating that the analyses were reasonably accurate. Inorganic carbon and the bound water of clays were not included, which offers at least a partial explanation for the low values.

Tables 7 and 8 present arithmetic and geometric means, minimum and maximum values, standard deviation, and the number of samples with values below detection limits. For the elements Ag, Cd, Mo, Se, U, and W, the large number of values below the detection limits makes the reliability of the statistical analysis of these elements suspect, since values below the detection limits were not included in any of the statistical treatment of the data. The presentation of both a geometric and an arithmetic mean serves as a quick method of estimating how nearly normal the distribution of a given

TABLE 6. Areas of little or no deposition in Lake Michigan

	Sample locations[a]							
	C-10	C-18	C-22	D-9	D-11	D-13	D-15	E-6
	E-8	E-16	E-20	E-28	E-40	E-41	F-7	F-17
Transitional areas (43)	G-6	G-8	H-7	H-9	H-15	I-16	I-18	I-24
	I-28	J-7	J-13	J-15	J-25	J-44	K-14	K-16
	L-17	L-35	N-37	R-41	R-42	S-41	T-50	U-44
	V-43	V-49	W-48					
	A-35	B-9	B-15	B-17	B-21	B-37	C-6	C-8
	C-12	C-14	C-16	C-24	C-26	D-3	D-5	D-7
	D-19	D-25	D-27	D-29	D-34	D-40	E-2	E-4
	E-18	E-30	E-32	E-34	F-1	F-3	F-5	F-21
	F-25	F-27	F-35	F-41	F-43	F-44	G-2	G-4
	G-16	G-18	G-20	G-22	G-26	G-28	G-36	G-41
	G-42	G-44	G-45	H-3	H-17	H-19	H-21	H-23
Nondepositional areas (128)	H-27	H-37	H-39	H-43	H-45	H-46	I-40	I-43
	I-44	I-45	J-3	J-41	J-46	K-4	K-26	K-42
	K-43	L-7	L-19	L-21	L-25	L-43	L-44	L-45
	M-8	M-18	M-30	M-46	N-13	N-15	N-39	N-47
	O-36	O-38	O-39	O-40	O-48	P-38	P-41	P-47
	Q-38	Q-39	Q-40	Q-41	Q-42	Q-44	Q-48	R-44
	S-38	S-42	S-43	S-44	S-48	T-38	T-39	T-40
	T-41	T-44	T-45	T-48	U-42	U-43	U-45	U-46
	U-48	U-49	U-50	V-44	V-45	V-48	W-43	X-48

[a] Refer to appendix 1 for explanation of sample locations.

TABLE 7. Mean values for trace element concentrations in 286 Lake Michigan surficial sediments

Element	Arithmetic mean (ppm)	Geometric mean (ppm)	Minimum (ppm)	Maximum (ppm)	Standard Deviation (ppm)	No. of values below detection limit
Ag	0.46	0.4	0.1	1.4	0.25	209
As	10.5	6.8	0.8	153	16	2
Ba	494	437	120	7400	497	
Be	1.7[a]	1.7[a]	0.9[a]	2.5[a]	0.4[a]	32
Br	33	18	0.8	175	32	
Cd	0.9	0.9	0.5	2.5	0.4	189
Ce	48	40	5	360	30	
Co	9.0	7.1	0.7	59	6.1	
Cr	46	34	3	176	32	
Cs	2.9	2.1	0.2	8.5	2.1	
Cu	22	13	1.0	84	19	7
Eu	0.8	0.7	0.2	1.9	0.3	
Ga	10	8.4	0.8	32	5.3	2
Hf	5.1	4.8	1.4	18	1.9	2
Hg	107[b]	77[b]	20[b]	800[b]	111[b]	2
La	23	21	6.4	76	11	
Lu	0.2	0.2	0.01	0.7	0.1	2
Mo	7	5.4	1	18	5	230
Ni	24	17	1	198	21	15
Pb	40	21	1	153	41	9
Rb	85	77	18	220	37	
Sb	1.1	0.8	0.1	4.7	0.9	
Sc	6.6	5.1	0.3	16.4	4.0	
Se	1.2	1.0	0.1	3.3	0.7	137
Sm	3.7	3.3	1	11	1.8	
Sr	132	122	30	340	54	14
Ta	0.5	0.4	0.1	1.6	0.3	1
Tb	0.5	0.4	0.1	1.4	0.2	
Th	5.8	4.9	0.4	13.6	3.0	
U	2.3	2.1	0.6	9.2	1.2	119
V	53[a]	35[a]	1.4[a]	130[a]	38[a]	7
W	1.1	1.1	0.4	2.7	0.5	140
Yb	1.7	1.5	0.4	6.0	0.8	
Zn	97	58	4	350	90	2
Zr	138[c]	116[c]	15[c]	281[c]	73[c]	

[a] Values were determined on 93 samples.
[b] Values in ppb.
[c] Values were determined on 103 samples.

element is. The ratio of the arithmetic mean to the geometric mean for most elements is 1.1 or 1.2, but high values for lead (1.9), Cu (1.7), Br (1.8), and Zn (1.7) indicate that these populations are skewed and contain a significant number of high values.

The mean and ranges of values reported here compare well with chemical data for Lake Michigan surficial sediments from Callender (1969), Leland, Shukla, and Shimp (1973), Robbins and Edgington (1976), and Torrey (1976). Histograms for arsenic (fig. 24), Br (fig. 25), organic carbon (fig. 26), Cr (fig. 27), Cu (fig. 28), Ga (fig. 29), La (fig. 30), MnO (fig. 31), Hg (fig. 32), Pb (fig. 33), Th (fig. 34), and Zn (fig. 35) illustrate the distribution patterns observed for major, minor, and trace elements in the surficial sediments of Lake Michigan. There are several general patterns. Arsenic, manganese oxide, and mercury have distributions with a few high values, but the majority of the population is in a relatively narrow range. This would indicate that a particular geochemical or environmental mechanism has concentrated these elements in a limited number of areas within the lake. The occurrence of ferromanganese nodules in a number of areas in the lake, particularly Green Bay, may be responsible for the high arsenic and manganese values.

Bromine, organic carbon, copper, lead, and zinc display a wide range of values, which includes many in a lower range but is not a true bimodal population. Chromium, gallium, lanthanum, and thorium have a narrower range of values than the other elements shown, and a definite bimodal distribution. This may indicate that these elements are sensitive indicators of two types of sedimentary environments.

Appendix 3 contains the first maps ever made of areal distributions of various chemicals over Lake Michigan, namely: As (fig. A), Br (fig. B), Cr (fig. C), Cu (fig. D), Ga (fig. E), Pb (fig. F), Hg (fig. G), Th (fig. H), Zn (fig. I), and organic carbon (fig. J).

The first observation that should be made for figures A to J is that areas with high concentrations of these elements generally correspond to depositional basins (fig. 23), to areas of type A muds (fig. 9), and to areas of silty-clay and clayey-silt (fig. 15). There are some exceptions, such as the very high values for arsenic in Green Bay (these will be discussed separately in the next section). Those elements tend to be concentrated along the eastern side of the southern basin, as shown by Shimp, Leland, and White (1970). Even though this area of the lake is surrounded by the highest population density and associated anthropogenic sources, in most cases the highest concentrations of these elements observed in the lake are not found there.

Individual samples often do not fit the pattern of surrounding samples. Sample location G-2, at the southern tip of Lake Michigan, has higher levels of chromium, copper, cobalt, and several other elements than would be expected, and may represent a location that is being influenced by a local source.

The samples were divided into the original categories of tables 5 and 6, arithmetic means were calculated, and the ratio between the mean value in depositional areas and the mean value in nondepositional areas was obtained. Tables 9 and 10 compare mean element concentrations between these two types of areas. For most of the major and minor elements (except phosphorus and organic carbon), the ratio between means for the two areas is 1.7 ± 0.7. Most trace elements have a similar ratio—1.8 ± 0.6—but bromine, chromium, cesium, copper, mercury, nickel, lead, antimony, scandium, vanadium, and zinc are exceptions. The highest ratios observed are 7.0 for lead, 6.7 for copper, 6.3 for organic carbon, 6.0 for bromine, and 5.9 for zinc. That only these few elements have such high ratios suggests that they have (at least) two sources.

If a single natural process, such as an erosional input from tributary streams, controlled the trace element distribution, then all the elements should have approximately the same ratio between the two types of areas. Because they do not, however, either a second component is needed, which could be anthropogenic, or a geochemical process is required that selectively concentrates only selected elements in the depositional areas of the lake.

Arsenic, lead, bromine, copper, chromium, mercury, zinc, and organic carbon have been shown by Shimp et al. (1971) and Shimp (1973) to be "accumulating" elements in southern Lake Michigan. These authors concluded that high levels of these elements were associated with sediment organic matter; the high levels were a consequence of man's activities, not a natural phenomonon. Their conclusions were based on the fact that substantially higher concencentrations of these elements were found near the sediment-

TABLE 8. Mean values for major and minor element concentrations and physical parameters of 286 Lake Michigan surficial sediments

Element	Arithmetic mean (%)	Geometric mean (%)	Minimum (%)	Maximum (%)	Standard deviation (%)	No. of values below detection limit
SiO_2	67	65	40	95	15	
Al_2O_3	7.2	6.4	1.6	15.4	3.2	
Fe_2O_3	3.1	2.5	0.3	10	1.9	
MgO	2.6	1.9	.01	8.8	1.6	9
CaO	4.0	3.0	0.2	16.4	2.7	
Na_2O	.62	.60	0.23	1.2	0.17	
K_2O	2.2	2.0	0.6	7.0	0.8	
TiO_2	0.3	0.3	0.01	0.7	0.2	
P_2O_5	0.16	0.11	0.01	0.8	0.13	10
MnO	0.21	0.11	.02	6.0	0.5	2
Total organic carbon	2.0	1.0	0.03	8.2	1.8	1
S	0.07	0.05	0.01	0.3	0.06	1
Cl	160[a]	150[a]	63[a]	360[a]	50[a]	
Ph -Log (H^+)	7.6	7.6	4.5	8.4	3.4	
Eh (eV)	+0.23	+0.17	-0.06	+.46	0.15	
Sand	44	19	0.2	99.9	38	
Silt	23	14	0.01	76	17	
Clay	30	17	0.08	79	25	
Mean grain size (ϕ)	5.1	4.3	-1.08	9	2.6	

[a] Values measured in ppm.

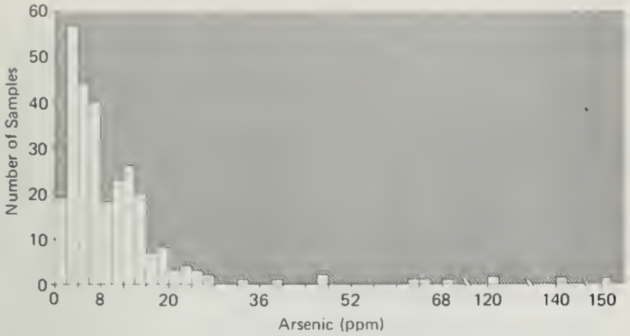

Figure 24. Arsenic distribution in Lake Michigan surficial sediments.

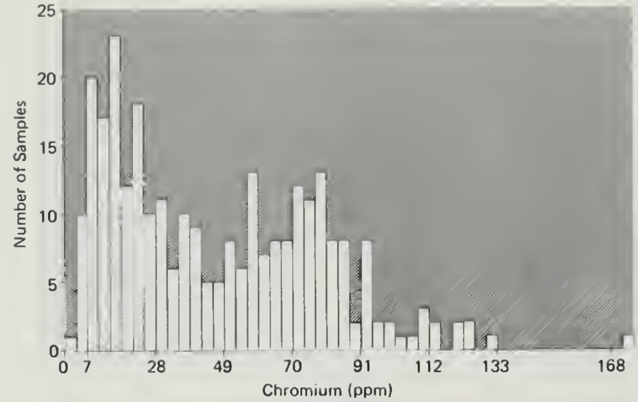

Figure 27. Chromium distribution in Lake Michigan surficial sediments.

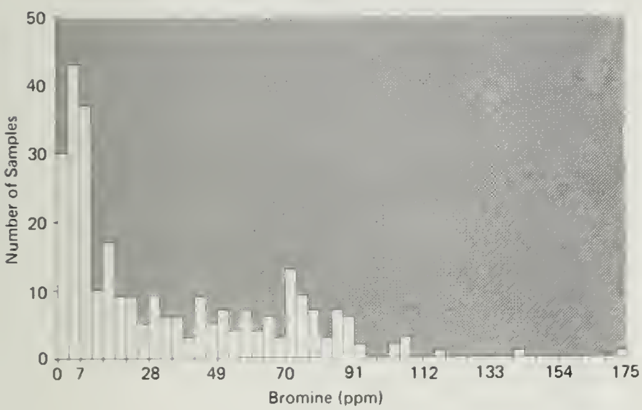

Figure 25. Bromine distribution in Lake Michigan surfical sediments.

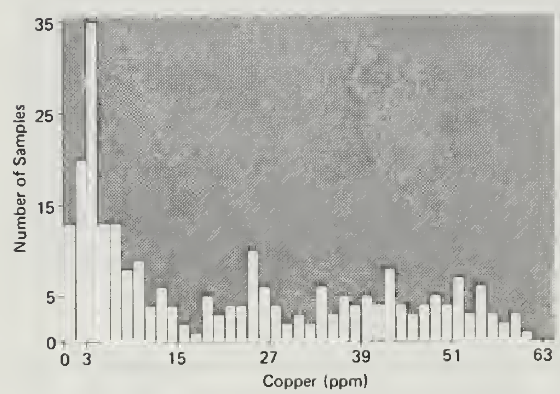

Figure 28. Copper distribution in Lake Michigan surficial sediments.

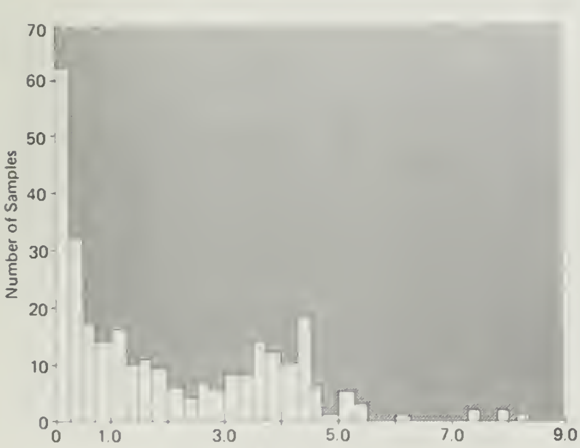

Figure 26. Organic carbon distribution in Lake Michigan surficial sediments.

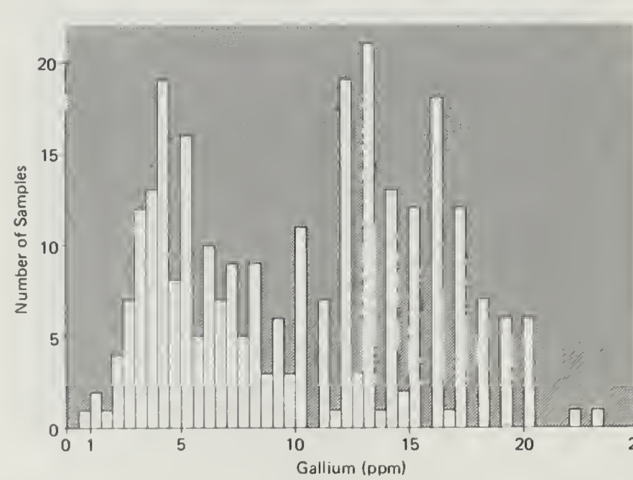

Figure 29. Gallium distribution in Lake Michigan surficial sediments.

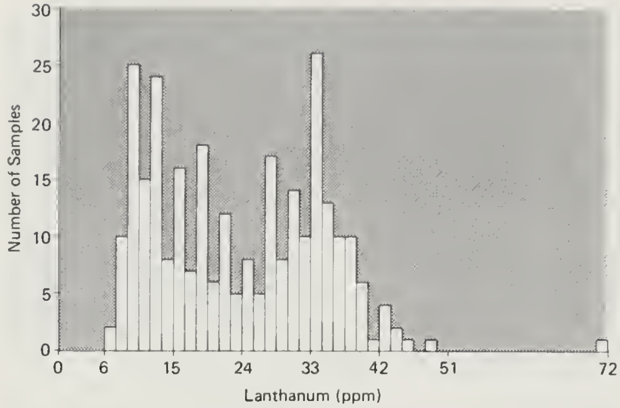

Figure 30. Lanthanum distribution in Lake Michigan surficial sediments.

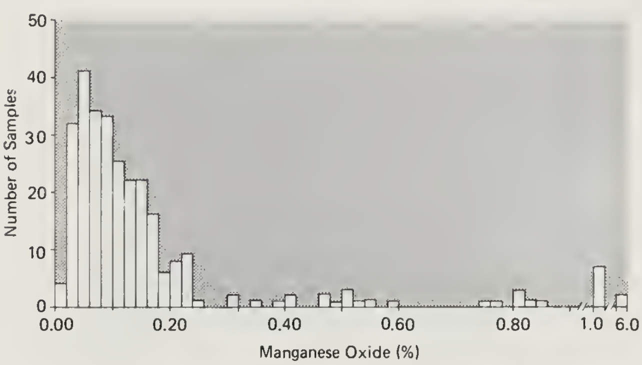

Figure 31. Manganese oxide distribution in Lake Michigan surficial sediments.

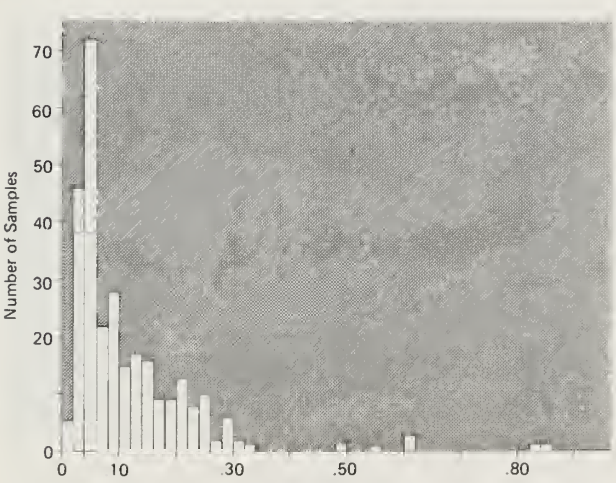

Figure 32. Mercury distribution in Lake Michigan surficial sediments.

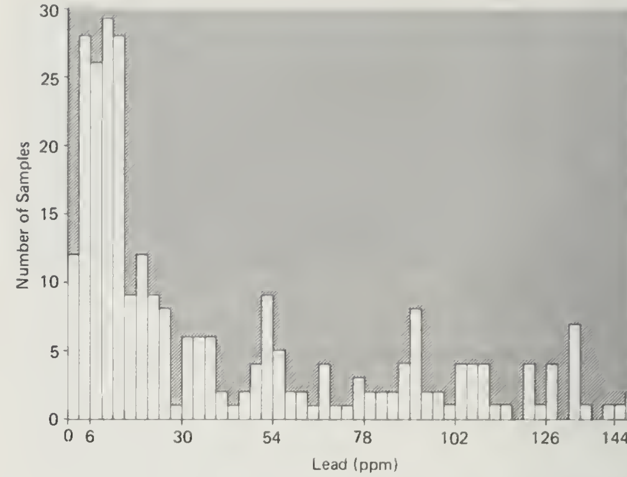

Figure 33. Lead distribution in Lake Michigan surficial sediments.

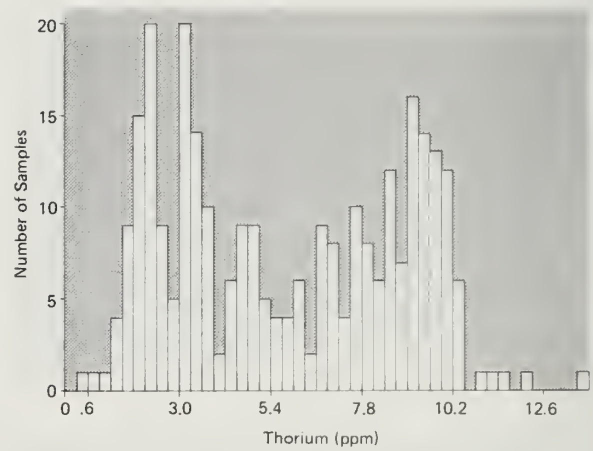

Figure 34. Thorium distribution in Lake Michigan surficial sediments.

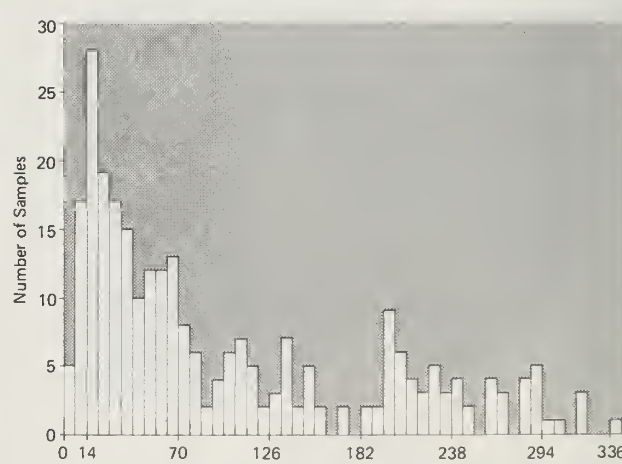

Figure 35. Zinc distribution in Lake Michigan surficial sediments.

TABLE 9. Trace element concentrations of depositional and nondepositional areas in Lake Michigan

Element	Nondepositional mean (ppm)	No.[a]	Depositional mean (ppm)	No.[a]	Ratio dep/non
Ag	0.3	26	0.6	43	1.8
As	9.4	125	12	113	1.3
Ba	430	127	510	113	1.2
Be	1.4	10	1.9	36	1.3
Br	10	127	60	113	6.0
Cd	0.9	10	1.0	80	1.1
Ce	34	127	62	113	1.8
Co	5.8	127	12.4	113	2.1
Cr	21	127	75	113	3.6
Cs	1.2	127	4.8	113	4.0
Cu	6.0	121	40	112	6.7
Eu	0.5	127	1.0	113	2.0
Ga	5.8	127	14	113	2.4
Hf	4.6	125	5.3	113	1.1
Hg	57[b]	127	176[b]	113	3.1
La	15	127	32	113	2.0
Lu	0.2	127	0.3	113	1.9
Mo	8	10	6	32	0.8
Ni	13	114	37	113	2.9
Pb	11	121	77	110	7.0
Rb	58	127	114	113	2.0
Sb	0.4	127	1.9	113	4.2
Sc	3.2	127	10	113	3.1
Se	0.8	127	1.5	113	1.9
Sm	2.4	127	5.1	113	2.1
Sr	109	127	151	113	1.4
Ta	0.3	127	0.7	113	2.5
Tb	0.3	127	0.6	113	2.0
Th	3.3	127	8.4	113	2.5
U	1.9	127	2.6	113	1.4
V	24	127	81	113	3.4
W	1.0	127	1.2	113	1.2
Yb	1.1	127	2.2	113	2.0
Zn	31	127	182	113	5.9
Zr	84	127	193	113	2.3

[a] No. = Number of samples.
[b] Values measured in ppb.

water interface than in the underlying sediments, and on the fact that the concentrations of the elements found in the suspended material were relatively high. Natural geochemical processes must be responsible for the incorporation of these anthropogenic elements preferentially into sediments of the depositional areas of the lake, rather than their being distributed uniformly over the lake bottom. Two important mechanisms are the adsorption of trace elements by clay minerals present in the clay-size fraction and the complexation of elements by organic compounds, of which humic substances in soils are probably the most important quantitatively.

Comparisons of mean concentrations in five sub-basins of Lake Michigan (see table 5 and fig. 23) are given in tables 11 and 12. The values in this study for the southern basin are in the same range as values reported by Robbins and Edgington (1976) and by Frye and Shimp (1973). There are only a few published chemical analyses of samples from the northern half of the lake, notably Callender's (1969) early work on the major element geochemistry of Lakes Michigan and Superior. The distributions of organic carbon and six other elements in the extreme lower end of Green Bay was reported by Leland and Shimp (1974). Their values agree with data of this study from grid locations A35, B35, B36, and B37.

Elemental means for the five sub-basins generally agree within ± 20 percent, although there are some exceptions. For example, the Green Bay Basin has the highest mean

TABLE 10. Major and minor element and physical parameters of depositional and nondepositional areas

Element	Nondepositional mean values (%)	Depositional mean values (%)	Ratio dep/non
SiO_2	80	53	0.6
Al_2O_3	4.6	10	2.1
Fe_2O_3	1.9	5	2.4
MgO	1.7	3.6	2.1
CaO	2.8	5.5	2.0
Na_2O	0.6	0.6	1.0
K_2O	1.6	2.7	1.7
TiO_2	0.2	0.5	2.7
P_2O_5	0.06	0.3	4.5
MnO	0.18	0.22	1.2
Total organic content	0.6	3.6	6.3
S	0.04	0.10	2.5
Cl	161[a]	158[a]	1.0
Ph	7.6[b]	7.7[b]	1.0
Eh	0.31[c]	0.11[c]	0.3
Sand	77	7.6	0.1
Silt	10	37	3.7
Clay	9	54	6.2
Mean grain size (ϕ)	2.7	7.6	2.8

[a] Values measured in ppm.
[b] Values measured in -Log (H^+).
[c] Values measured in eV.

values for mercury and manganese, and the Grand Haven Basin has higher levels of chromium, lead, and zinc than the other sub-basins. These exceptions may reflect local sources or the occurrence of a few high values that distort the overall average. The fact that the five sub-basins agree so well in elemental averages implies either that the sources of most elements are distributed uniformly around the lake, or that mixing in Lake Michigan is effective, or both.

Enrichment factors demonstrate which elements occur in concentrations above the reference value and may indicate trends not otherwise apparent. Trace element enrichment factors were calculated relative to Mason's (1966) crustal and shale averages and Vinogradov's (1959) average soil. They were calculated by dividing the arithmetic means for trace elements in table 8 by concentrations of the reference materials in table 13. For most of the trace elements, enrichment factors were less than 2.0, no matter which reference concentrations were used. This implies that the concentrations of most trace elements in Lake Michigan are no higher than would be expected from natural processes, free of anthropogenic effects. For silver, cadmium, hafnium, and molybdenum, the enrichment factors are probably unreliable because of uncertainties in the analytical data and in the reference concentrations.

Arsenic, bromine, antimony, lead, and possibly mercury are the only elements enriched relative to crustal abundances, and only bromine is enriched relative to the average soil or shale. One interpretation of these factors is that natural sources are capable of supplying the concentrations of most trace elements seen in an average Lake Michigan sediment. There are significant differences, however, in trace element content between the depositional and nondepositional areas of the lake (table 9) and between the surficial and buried sediments.

Ferromanganese nodule occurrences

In Green Bay, elevated levels of a number of chemical elements in the sediments—notably arsenic, barium, manganese, and iron—suggest that a local geochemical process or source is important. One possible explanation is that ferromanganese nodules or concretions were observed in surface sediments from a number of locations in Green Bay and extreme northwestern Lake Michigan. The location of the nodules, found in a 1975 grid sampling program, were: D-39, D-40, E-40, F-41, F-44, G-44, H-45, H-46, M-46, N-47, V-46, V-44, and V-45. Explanations of these locations can be found in appendix 1.

The geochemistry and occurrence of ferromanganese nodules in Green Bay has been discussed by Rossmann and Callender (1969), Edgington and Callender (1970), Rossman, Callender, and Bowser (1972), and Robbins and Callender (1975). Freshwater ferromanganese nodules in Lake Ontario have been reported by Damiani, Morton, and Thomas (1973) and Cronan and Thomas (1972); Cook and Felix (1975) found these nodules in Saranac Lake system in New York. Sly and Thomas (1974) outlined the occurrences of ferromanganese-coated sand, Fe, Mn layers, and nodule

TABLE 11. Mean trace element concentrations in depositional sub-basins

Element	Southern Basin (ppm)	No.[a]	Northern Basin (ppm)	No.[a]	Milwaukee Basin (ppm)	No.[a]	Grand Haven (ppm)	No.[a]	Green Bay (ppm)	No.[a]
Ag	0.6	18	0.5	18	0.9	3	1.0	2	0.4	1
As	12.5	33	11	50	11	7	17	10	15	8
Ba	536	33	505	50	538	7	468	10	479	8
Be	1.8	10	2.0	17	2.0	4	1.8	2	1.8	2
Br	54	33	62	50	81	7	51	10	62	8
Cd	1.1	25	0.9	34	1.0	4	1.0	9	0.8	8
Ce	60	33	63	50	63	7	63	10	72	8
Co	12	33	13	50	13	7	13	10	14	8
Cr	83	33	72	50	70	7	91	10	61	8
Cs	4.6	33	5.1	50	5.1	7	5.3	10	3.1	8
Cu	39	33	41	50	49	7	43	10	31	8
Eu	0.9	33	1.0	50	1.0	7	1.0	10	1.2	8
Ga	13	33	14	50	16	7	16	10	12	8
Hf	5.0	33	5.4	50	5.8	7	4.8	10	6.3	8
Hg	168[b]	33	156[b]	50	118[b]	7	205[b]	10	401[b]	8
La	30	33	32	50	36	7	33	10	33	8
Lu	0.3	33	0.3	50	0.4	7	0.3	10	0.3	8
Mo	7	9	6	14	3	3	9	3	6	2
Ni	34	33	37	50	34	7	37	10	54	8
Pb	88	33	68	50	77	7	98	10	57	8
Rb	110	33	122	50	125	7	111	10	93	8
Sb	2.0	33	1.9	50	2.4	7	2.3	10	1.8	8
Sc	10	33	10	50	11	7	10	10	10	8
Se	1.3	28	1.5	40	1.5	7	1.5	10	2.1	8
Sm	4.7	33	5.2	50	5.5	7	5.4	10	5.7	8
Sr	168	33	141	50	140	7	144	10	174	8
Ta	0.8	33	0.7	50	0.7	7	0.8	10	0.6	8
Tb	0.6	33	0.6	50	0.7	7	0.6	10	0.7	8
Th	8.1	33	8.7	50	9.1	7	9.0	10	9.0	8
U	2.7	29	2.7	39	2.6	5	2.3	9	3.1	7
V	77	10	88	17	87	4	89	2	68	2
W	1.2	29	1.2	26	1.6	7	1.5	9	1.2	6
Yb	2.3	33	2.3	50	2.4	5	2.3	10	2.5	8
Zn	198	33	173	50	182	5	228	10	119	8
Zr	179	12	194	18	240	4	206	3	194	2

[a] No. = number of samples.
[b] Values measured in ppb.

occurences in the Great Lakes. The origin of these nodules in freshwater lakes has been discussed by Harriss and Troup (1969).

Rossmann and Callender (1969) proposed that the major source of manganese for growth of nodules is the interstitial water, which in northern Lake Michigan and Green Bay is high in iron and manganese derived from the Canadian Shield. As interstitial water migrates upward toward the sediment-lake water interface, iron is constantly being removed, but little manganese is precipitated. Upon contact with lake water, the pronounced change in Eh causes a rapid precipitation of iron and manganese as a poorly crystallized mixture of hydrated oxides and hydroxides. In areas with a low sedimentation rate and firm bottom, the nodules persist. In an area like southern Green Bay, which is floored by silt or mud, the nodules are buried by sediment, and they redissolve.

Cronan and Thomas (1972) demonstrated the importance of two mechanisms in the origin and variations in composition of Lake Ontario concretions. The first mechanism is the upward diffusion of reduced iron and manganese from the underlying sediments, and the second is the movement of deep waters enriched in Mn and Fe, creating a condition of Fe and Mn precipitation as the redox potential and possibly the pH is increased. They concluded that estimating the relative importance of each mechanism was difficult and that the composition and circulation of deep basin waters required further investigation.

TABLE 12. Mean major and minor element concentrations and physical parameters among depositional sub-basins

Element	Southern Basin[a] (%)	Northern Basin[b] (%)	Milwaukee Basin[c] (%)	Grand Haven[d] (%)	Green Bay[e] (%)
SiO_2	49	54	52	52	54
Al_2O_3	10	10	10	10	9
Fe_2O_3	4.7	4.6	4.5	5.0	5.1
MgO	4.4	3.2	3.6	3.7	2.2
CaO	7.6	4.4	4.7	5.4	3.3
Na_2O	0.6	0.6	0.7	0.5	0.6
K_2O	2.5	2.9	2.7	2.7	2.5
TiO_2	0.5	0.5	0.5	0.5	0.5
P_2O_5	0.26	0.27	0.31	0.25	0.31
MnO	0.16	0.23	0.10	0.25	0.50
T.O.C.	3.9	3.1	3.8	3.9	5.0
S	0.1	0.09	0.09	0.1	0.2
Cl	163[f]	152[f]	164[f]	148[f]	171[f]
Ph	7.8[g]	7.6[g]	7.7[g]	7.8[g]	7.2[g]
Eh	0.11[h]	0.13[h]	0.09[h]	0.06[h]	0.10[h]
Sand	6.6	7.4	6.7	8.2	10
Silt	43	31	36	37	46
Clay	47	62	57	55	44
Mean grain size (ϕ)	7.2	8.0	7.8	7.8	7.0

[a] Number of samples = 33.
[b] Number of samples = 50.
[c] Number of samples = 7.
[d] Number of samples = 10.
[e] Number of samples = 8.
[f] Values measured in ppm.
[g] Values measured in -Log (H^+).
[h] Values measured in eV.

Of interest to this study is the minor element of geochemistry of ferromanganese nodules and their ability to concentrate trace elements. The adsorptive power of precipitated ferromanganese oxide coatings is great and hence many minor elements would be expected to occur in these deposits. Edgington and Callender (1970) analyzed 10 ferromanganese nodules from Green Bay for 22 elements by neutron activation analysis, and found that arsenic and barium were much more highly concentrated than the other trace elements. Cronan and Thomas (1972) found that lead and zinc were concentrated on ferromanganese oxide coatings, as were Ni, Cu, and Co to a lesser degree. Barium and lithium were highly enriched in comparison to deep sea nodules; the concentration ranges observed for the remaining elements were less than those observed in deep sea nodules but comparable to values reported for freshwater nodules.

Statistical treatment of the results

In order to elucidate relationships among the 55 types of chemical and physical measurements made on the 286 samples of this study, a number of statistical techniques were employed.

Linear correlations were computed for the entire data set to establish which element concentrations and physical parameters were important in controlling the variability of the sytem. Selected correlations observed in Lake Michigan surfical sediments are listed in table 14. The entire correlation matrix is not included because the variability of the system is controlled by only a few factors, as will be seen.

Bromine, organic carbon, lead, manganese, and clay-sized sediment were the factors chosen for discussion and included in table 14. These particular elements were chosen for varying reasons. Numerous investigators have shown that clay-sized sediments and organic carbon control the distribution of heavy metals. Lead is a prominent anthropogenic element that is useful as a tracer for atmospheric input into the lake. Manganese was chosen to see which element abundances correlated with the presence of hydrous ferromanganese oxides and nodules. Bromine has one of the highest enrichment factors and may have inputs from soil-borne and aerosol particles produced by the combustion of leaded gasoline.

The association of bromine with the combustion of leaded gasoline is well established. Bromine was found to be on small particles (Ondov, 1974), in the gaseous form (Moyers et al., 1972), and in lead-bromochlorine compounds (Biggins and Harrison, 1979). The mass balance models of Lake Michigan proposed by Harrison et al. (1971), Winchester and Nifong (1971), and Klein (1975) have indicated that the combustion of leaded gasoline is the major source of bromine in Lake Michigan. The geochemical properties of bromine aerosls are no doubt different from lead once they are deposited on the lake or the surrounding watershed. Bromine was suggested by Leland, Shukla, and Shimp (1973) to be associated with the hydrous oxide and organic fractions of suspended matter and possibly incorporated by aquatic organisms.

The mineralogy of the clay-sized fraction in Lake Michigan sediments, as reported by Shimp, Leland, and White (1970) for samples collected in the Southern Basin, consisted of dolomite, calcite, quartz, illite, chlorite, and expandable clay minerals present in the less than 2-micron clay-sized fraction. Clay mineral data were reported as ratios of diffraction effects and were not considered as percentages. Callender (1969) also reported the mineral content for 50 sediment samples collected in Lake Michigan. The percentages of the total mineral composition in the surface sediments were 61 percent quartz, 6 percent potassic feldspars, 6 percent sodic feldspars, 3 percent calcite, 17 percent dolomite, and 7 percent clay minerals.

According to Sly and Thomas (1976) and Kemp et al. (1976), major element analysis is useful in indicating the predominant mineral phases present in Great Lake sediments. The bulk mineralogical composition of the sediments of Lakes Ontario and Huron were related to diagnostic major elements and sediment texture by Sly and Thomas (1974). They found that the detrital quartz and feldspar showed positive correlation with the Na_2O and SiO_2 content, and they thought that illite and chlorite were the predominant clay minerals that correlated with Al_2O_3, TiO_2, K_2O, and MgO. Calcium carbonate was the primary form of CaO, whereas Fe_2O_3 was predominantly in the form of hydrated iron oxide, although a strong relation with Al_2O_3 was also apparent.

Most element abundances correlate positively with abundances of clay-sized sediments (table 14). The exceptions include calcium, magnesium, and strontium (whose abundances are probably controlled by calcite precipitation, manganese, barium, and arsenic taken up in ferromanganese nodules), and silicon, which is concentrated in coarse-grained terrigenous sediments. The high correlations observed between Al_2O_3, TiO_2, K_2O, and P_2O_5 and the clay-sized fraction provide indirect evidence that the clay-sized material is predominantly composed of clay minerals. Investigating this correlation further by directly measuring the mineralogy of the samples collected would be informative.

Leland, Shukla, and Shimp (1974) discussed the affinity of clay minerals for trace elements in recent sediments, and pointed out the selectivity of different clay minerals for trace cations and the role of natural complexing agents in altering the retentive properties of clays. The trace elements that have been shown to have possible anthropogenic sources—namely bromine, Cr, Cu, Pb, and Zn—all have high correlations with the clay-sized fraction. The incorporation of trace elements into the clay-sized sediments could be controlled by the ion exchange capacity of clay minerals, but fine particulate organic matter (closely associated with fine clay) and hydrous oxides could also be important in the transport of trace elements.

High correlations were also observed between most elemental abundances and the organic carbon contents of the sediments. Kemp (1971) found the organic carbon content to be directly proportional to the clay-sized fraction of sediment in Lakes Erie, Ontario, and Huron. Suspended

TABLE 13. Enrichment factors observed in Lake Michigan surficial sediments

Element	Crustal ave[a]	Soil[b]	Shale[a]
Ag	7.1	0.5	7
As	4.4	1.6	1.0
Ba	1.6	0.6	0.8
Be		0.2	3.2
Br	10	5.5	1.4
Cd		3	1.1
Ce	1.1	1.6	0.5
Co	0.2	0.4	0.5
Cr	0.2	0.3	0.5
Cs	1.3	0.2	0.5
Cu	0.2	0.4	0.5
Eu	1.0	0.8	0.6
Ga	0.4	0.2	0.5
Hf	2.7	1.3	0.3
Hg	3.0	0.3	1.8
La	1.1	0.6	0.5
Lu		1.0	0.3
Mo	4.4	3.5	2.7
Ni	0.2	0.2	0.3
Pb	6.6	2.0	2.0
Rb	0.8	0.2	0.6
Sb	6.8	1.1	0.7
Sc	0.1	0.7	0.5
Se		2.0	2.0
Sm	0.9	0.7	0.5
Sr	0.3	0.3	0.4
Ta		0.1	0.2
Tb	0.8	0.5	0.6
Th	1.4	0.5	0.5
U	2.1	0.7	0.6
V	0.2	0.4	0.2
W	1.3		0.7
Yb	1.0	0.8	0.4
Zn	0.9	1.2	1.0
Zr	0.8	0.7	0.9

[a] Mason, 1966
[b] Vinogradov, 1959

TABLE 14. Selected correlations observed in Lake Michigan surficial sediments

Element	Clay	Total organic carbon	Pb	Mn	Br
Al_2O_3	0.88	0.65	0.59	0.01	0.69
CaO	0.32	0.47	0.42	-0.14	0.21
Fe_2O_3	0.70	0.63	0.55	0.40	0.63
K_2O	0.68	0.47	0.43	-0.01	0.56
MgO	0.41	0.59	0.50	-0.12	0.36
MnO	0.03	0.17	0.06	—	0.25
P_2O_5	0.76	0.70	0.54	0.25	0.76
SiO_2	-0.81	-0.79	-0.71	-0.06	-.69
As	0.05	0.18	0.11	0.78	0.23
Ba	0.04	0.13	0.05	0.88	0.21
Br	0.73	0.73	0.63	0.25	—
Ce	0.50	0.52	0.39	0.68	0.61
Co	0.55	0.54	0.44	0.68	0.62
Cr	0.78	0.71	0.77	-0.01	0.64
Cs	0.86	0.64	0.64	-0.01	0.70
Cu	0.86	0.78	0.85	0.03	0.77
Eu	0.76	0.64	0.58	0.36	0.73
Ga	0.82	0.60	0.63	0.00	0.68
Hf	0.63	0.04	-0.01	-0.05	0.13
Hg	0.42	0.54	0.60	0.02	0.38
La	0.77	0.62	0.55	0.44	0.74
Lu	0.72	0.53	0.45	0.06	0.60
Ni	0.54	0.57	0.48	0.00	0.67
Pb	0.63	0.73	—	0.06	0.63
Rb	0.81	0.55	0.50	0.00	0.64
Sb	0.67	0.71	0.79	0.34	0.70
Sc	0.89	0.69	0.62	0.00	0.73
Sm	0.78	0.65	0.56	0.40	0.74
Sr	0.34	0.34	0.28	0.16	0.35
Ta	0.76	0.61	0.64	0.05	0.61
Tb	0.67	0.57	0.46	0.26	0.64
Th	0.87	0.66	0.60	0.02	0.72
Yb	0.72	0.57	0.51	0.12	0.63
Zn	0.72	0.74	0.94	0.14	0.68
Sand	-0.82	-0.73	-0.70	-0.47	-.71
Silt	0.63	0.70	0.64	0.61	0.73
Clay	—	0.68	0.63	0.32	0.73

material in Lake Michigan was found to contain 30 to 40 percent organic material (Leland, Shukla, and Shimp, 1973). This material could be expected to have high ion exchange capacities that are at least partly composed by humic acids. It is difficult to directly determine which mechanism is the controlling factor in the incorporation of particular trace elements in the fine-grained samples of Lake Michigan. Organic carbon coatings on silt- and clay-sized sediments could be more important than ion exchange with clay minerals. The indirect evidence provided by statistical analysis of the data is not a direct answer to this question.

Many trace elements correlate with lead, especially those that have high enrichment factors, such as copper and zinc. Such correlations do not require that these elements have the same source or geochemical behavior.

Arsenic, barium, cerium, and cobalt have moderate to high positive correlations with manganese, whereas the other elements show little or no correlation. Highly selective adsorption of trace elements by hydrous ferromanganese oxides, which are restricted to localized areas of the lake, is indicated.

Bromine has a strong positive correlation with organic carbon and with abundances of clay-sized material and, therefore, with all of the trace elements associated with the latter two materials.

Correlations were also calculated for individual subbasins (table 5), for samples from depositional areas, and for samples from nondepositional areas (table 6). These correlations are weaker than those of table 14. Fewer samples are involved in each case, and the ranges of values are smaller, so the factors are less reliable and more difficult to interpret.

A number of researchers (Hopke, 1976; Thomas, Kemp, and Lewis, 1973; Callender, 1969) have applied multivariate factor analysis to the interpretation of physical and chemical parameters of lake sediments. Sievering et al. (1979) have applied factor analysis to the interpretation of chemical and meterological data collected on aerosols collected over Lake Michigan. A good explanation of the rationale for this approach can be found in Hopke (1976) and Sievering et al. (1979).

Factor analysis is a statistical tool in which the relationships between variables are summarized in a matrix of factors. In general, enough factors are chosen to account for about 90 percent of the system variance, with no prior assumptions made concerning the data or the resulting factors. To account for 100 percent of the variance in this study, there would have to be 44 factors because there are 44 chemical and physical parameters for which the data sets are sufficiently accurate and complete to merit inclusion in factor analysis. The loading values that emerge from the ensuing calculation specify what portion of the total concentration of each element can be attributed to each factor.

Table 15 contains the results obtained from an orthogonally rotated factor matrix, generated by computer program SOUPAC (Computing Services Offices, 1979). Only 44 parameters were included in the evaluation instead of the full 55. Parameters for which there were incomplete data sets, a significant number of below detection limit values, or analytical data of dubious accuracy were excluded. Seven factors were found to account for 87 percent of the variance of the sytem. The distribution of variance in the system when these seven factors were specified in the varimax factor rotation is included in table 15.

Factor 1 accounts for 48.6 percent of the variance of the system and has high loadings for 22 of the chemical elements. This factor is thought to represent abundance of clay-sized sediment and the abundant elements derived from shoreline erosion and river input. All the rare earths except cerium have a high loading on this factor. This is expected because of their similar geochemistries and because the crust is the primary source for these elements.

Factor 2 accounts for 16 percent of the variance and has high loadings for many trace elements with high enrichment factors that are thought to be anthropogenic in origin. Silt, organic carbon, and sulfur also have high loadings on Factor 2; therefore, this factor probably represents fine-grained sediments containing silt-sized material. The fact that S, Hg, Pb, Sb, and Zn have volatile forms could suggest an atmospheric source to the lake. The strong negative loading for Eh indicates that this factor is not an oxidizing environment. Sulfide minerals and organic carbon would be stable and may control a number of the trace element loadings in this factor.

Factor 3 is clearly related to the occurrence of hydrous ferromanganese nodules. Iron, manganese, arsenic, barium, nickel, and chromium, which have high loadings, have all been identified earlier in this report as having a geochemical association with ferrogmanganese nodules. The high loading for cerium may be an artifact of the analytical technique because high iron values can interfere with the determination of cerium by INAA. Cerium, however, does have a different oxidation state than the other rare earths, so that the high loading could be valid.

Factor 4 contains high loadings of magnesium and calcium, which reflects the presence of carbonates in the sediment. It is not clear why strontium or barium do not show significant loading here.

Factors 5, 6, and 7 do not have satisfactory explanations, which is unfortunate because loadings for Na, Cl, Sr, Hf, and pH are distributed among these factors. It should be noted, however, that these three factors only account for 10 percent of the variance of the data.

The use of road salts in the Lake Michigan Basin has been suggested by Torrey (1976) as a possible source of sodium and chlorine in the lake. Factor 5 could be related to the introduction of road salts into the lake during spring runoff.

It is not surprising that pH requires a separate factor for its description because studies by Thomas, Kemp, and Lewis (1972, 1973) and Thomas et al. (1976) have shown that pH has no consistent pattern in Lakes Erie, Ontario, or Huron.

Silicon, abundance of sand-sized particles, and Eh have negative loadings on nearly all of the factors. If more factors had been chosen, silicon and sand-sized material would probably have their dominant loadings on a nearshore factor.

Another statistical technique used in this study is the Parks cluster analysis. This technique, also used by Hopke (1976), was very useful in grouping samples. A cluster program utilizes correlation coefficients and gives a measure of the degree of similarity between the samples. The details of the particular program used can be found in Parks (1969).

The 32 parameters chosen for cluster analysis were those whose behavior was best understood and for which there were complete and reliable data sets. Loadings were calculated for three principal-axis factors. For each sample, a loading value is derived and a distance function is calculated that relates each sample to the one other sample that has the most similar loading values. The results are then plotted as clusters, which are grouped into progressively larger clusters that have decreasing similarity until one group encompasses the entire data set (fig. 36).

The ideal result would be the emergence of clusters that would not only separate depositional from non-

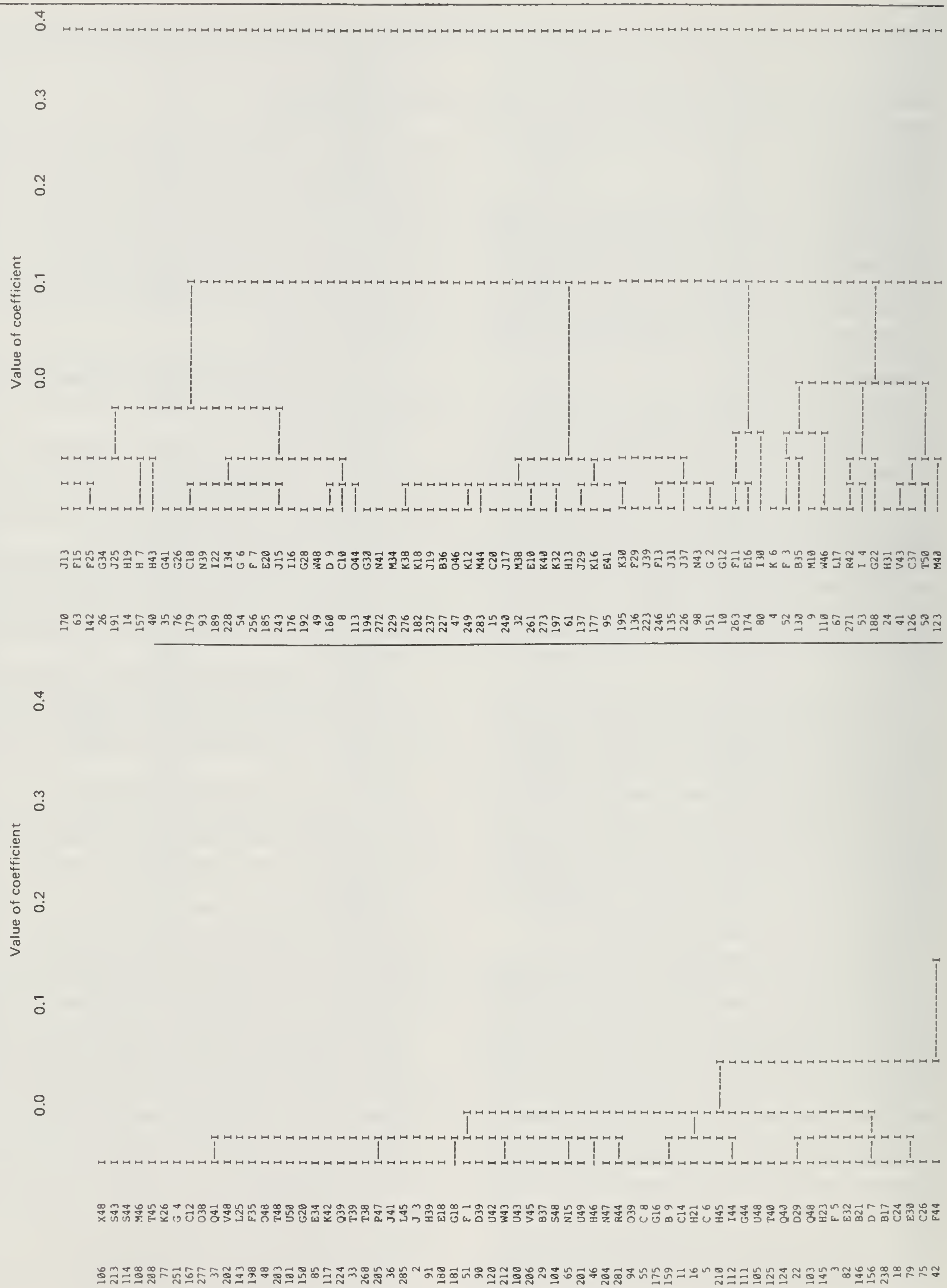

Figure 36. Cluster analysis of Lake Michigan, using 32 elements.

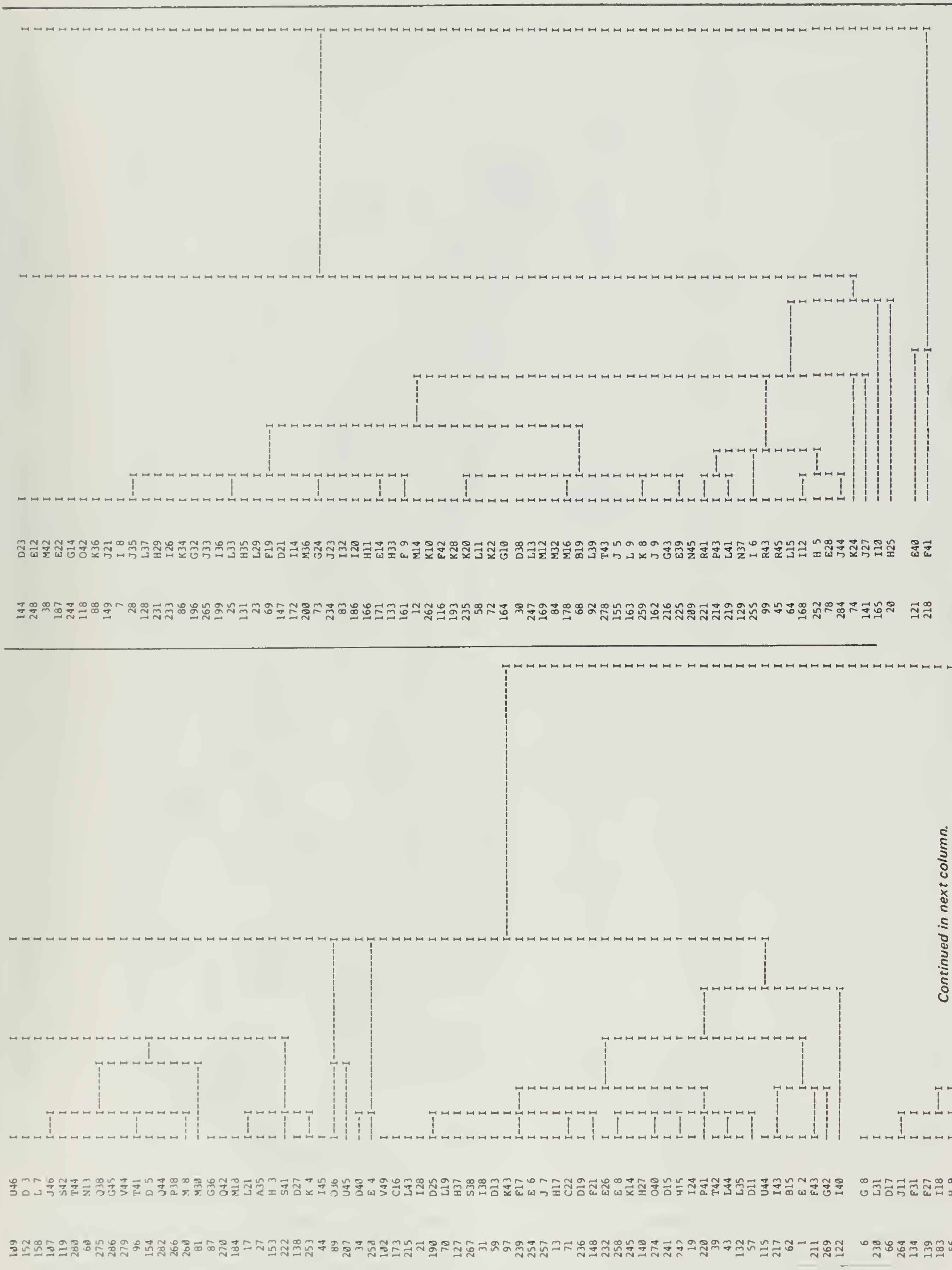
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TABLE 15. Orthogonally rotated factor matrix for Lake Michigan surficial sediments

Elements	Factor 1	2	3	4	5	6	7
SiO_2	-0.71	-0.41	-0.15	-0.49	-0.13	-0.05	-0.02
Al_2O_2	0.90	0.19	0.07	0.10	0.16	0.00	0.03
Fe_2O_3	0.65	0.28	0.51	0.15	-0.19	0.05	0.02
MgO	0.36	0.30	-0.07	0.80	0.22	0.01	0.05
CaO	0.21	0.23	-0.04	0.88	0.11	-0.04	0.05
Na_2O	0.27	-0.24	-0.07	0.07	0.63	0.42	-0.01
K_2O	0.73	0.16	0.03	-0.04	0.20	0.18	0.02
TiO_2	0.86	0.29	0.10	0.19	0.03	0.13	0.02
P_2O_5	0.70	0.36	0.33	0.10	0.03	0.00	0.00
MnO	-0.07	0.02	0.94	-0.10	0.01	-0.05	-0.01
TOC	0.52	0.61	0.23	0.24	0.15	-0.12	-0.04
S	0.29	0.62	0.04	0.28	0.17	0.18	-0.09
Cl	-0.23	0.15	-0.19	0.41	0.62	0.01	0.03
As	-0.01	0.08	0.85	0.00	-0.26	0.04	0.02
Ba	-0.01	-0.04	0.90	-0.02	0.03	0.06	0.02
Br	0.66	0.44	0.29	-0.10	0.24	-0.11	-0.01
Co	0.54	0.10	0.78	0.05	0.05	-0.07	0.03
Cr	0.76	0.44	0.07	0.27	-0.08	-0.02	0.06
Cs	0.89	0.26	0.05	0.13	-0.04	-0.05	0.04
Cu	0.75	0.55	0.07	0.06	0.07	-0.15	0.03
Ga	0.85	0.23	0.08	0.07	0.11	0.03	-0.01
Hf	0.18	0.05	0.00	-0.02	0.21	0.88	-0.01
Hg	0.23	0.72	0.04	0.03	-0.04	0.26	-0.01
Ni	0.49	0.28	0.64	-0.06	0.18	-0.09	-0.03
Pb	0.46	0.75	0.10	0.14	0.02	-.14	0.09
Rb	0.89	0.10	0.08	0.09	0.03	0.09	0.07
Sb	0.58	0.60	0.15	0.12	-0.06	-0.04	0.08
Sc	0.93	0.21	0.09	0.17	0.07	0.01	0.02
Sr	0.32	0.05	0.24	0.18	0.50	0.16	0.12
Ta	0.77	0.33	0.05	0.27	-0.09	0.18	0.06
Th	0.90	0.24	0.10	0.13	0.01	0.08	0.04
Zn	0.54	0.70	0.17	0.15	-0.01	-0.13	0.07
Ce	0.48	0.10	0.78	0.03	0.09	0.01	0.02
Eu	0.77	0.21	0.47	0.10	0.12	0.10	-0.01
La	0.77	0.17	0.54	0.05	0.05	0.03	-0.02
Lu	0.78	0.13	0.15	0.11	-0.04	0.21	0.05
Sm	0.78	0.19	0.50	0.06	0.07	.05	-0.02
Yb	0.76	0.19	0.22	0.16	0.00	0.22	0.03
Eh	-0.27	-0.71	-0.02	-0.18	0.12	.06	0.03
Ph	0.09	-0.01	0.02	0.06	0.06	-.01	0.97
Sand	-0.77	-0.41	-0.05	-0.22	-0.11	-0.4	0.09
Silt	0.49	0.51	0.03	0.43	0.25	0.21	-.04
Clay	0.88	0.30	0.06	0.05	0.06	-0.04	.00
Mean	0.83	0.38	0.05	0.13	0.13	.04	.01
% variance	48.6%	16.5%	15.8%	7.6%	4.6%	4.0%	2.9%
Cumulative % variance	48.6%	65.1%	80.9%	88.5%	93.1%	97.1%	100%

depositional areas, but also distinguish different sub-basins or areas of the lake. Figure 46 illustrates that there was no north-south or east-west trend in the different clusters; however, there were three apparent subpopulations. The first group is read top to bottom as X-48 to I-40, group 2 is G-8 to 0-44, and group 3 is G-30 to F-41. An areal distribution of these three groups on Lake Michigan was made, and the resulting figure (fig. 37) was similar to figures 9, 14, and 23. There were remarkably few misclassifications.

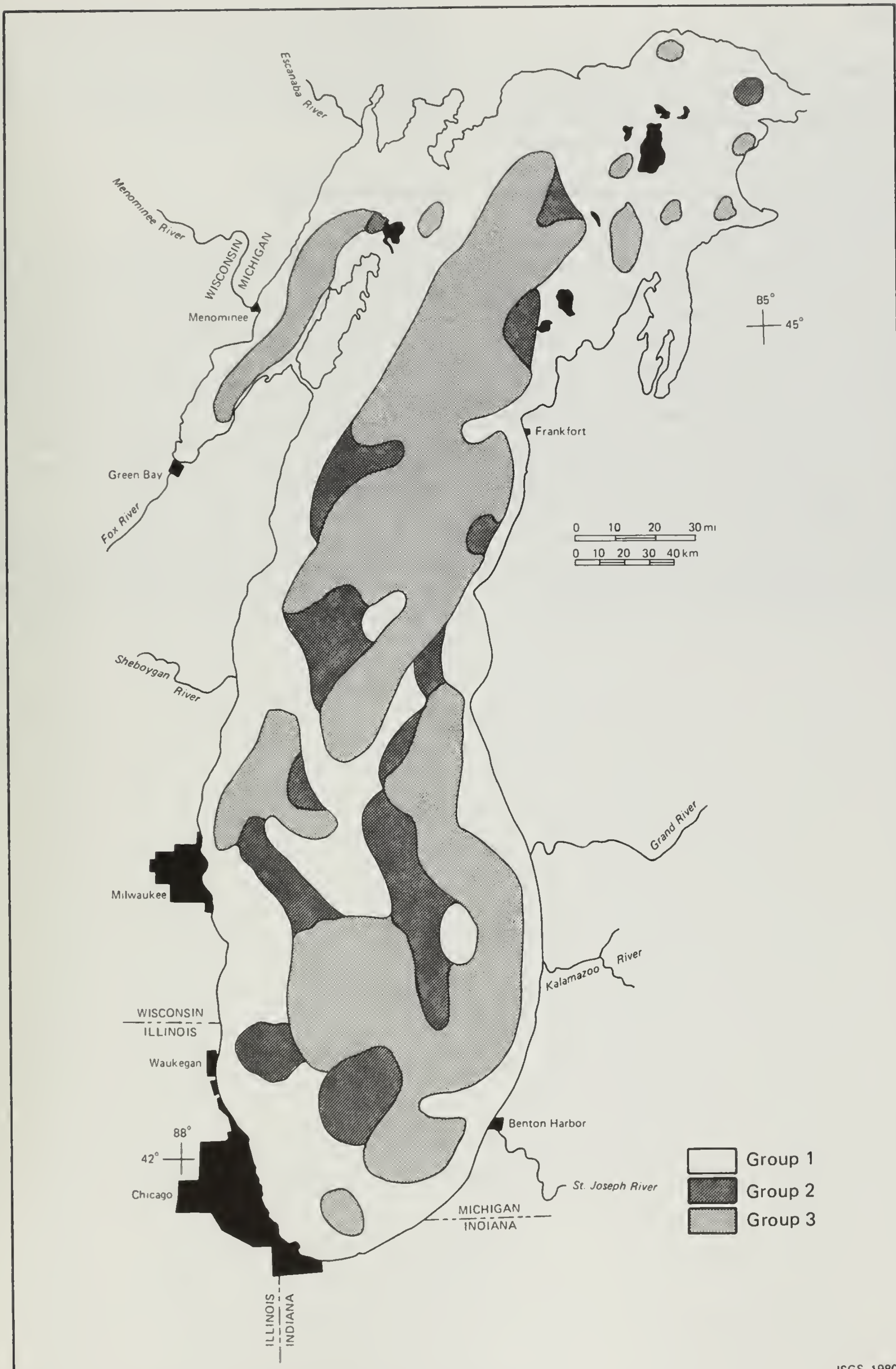

Figure 37. Classification of Lake Michigan bottom sediments through cluster analysis.

CONCLUSIONS

This study provides a data base for further studies of the geochemical character of recent sediments in Lake Michigan. Distributions are reported for concentrations of 48 chemical elements, for pH and Eh, and for grain size measured on 286 samples. Chemical analyses were made in two independent laboratories, using a variety of analytical techniques, so that the results should be of superior accuracy.

The variations between depositional and nondepositional areas in Lake Michigan can be delineated from plots of the clay-sized sediment distribution, from mean grain size information, and from the organic carbon distribution. Bromine, chromium, copper, lead, and zinc are elements that have much higher enrichments in the depositional areas than in the nondepositional areas of the lake.

Differences in concentrations of most elements between depositional sub-basins in Lake Michigan are not significant. The Southern Basin could have been expected to have higher levels of anthropogenic-associated elements because of the large population centers surrounding it; however, because of the efficient mixing of local source materials by lake currents prior to incorporation into the sediment, or because of long-range transport of elements associated with air pollution, such differences seem to be averaged over the lake.

Statistical treatment of the data indicates that the factors controlling the distribution of elements, particularly the potentially hazardous heavy metals, appear to be the incorporation of heavy metals into organic matter and clay mineral present in the finer grained sediments.

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APPENDIX 1

SAMPLE LOCATIONS

Geol. no.	Latitude	Longitude	Depth (m)	Lab. no.
A 35	44 DEG. 42. MIN. 10. SEC. N	87 DEG. 53. MIN. 0. SEC. W	26.	R13058
B 9	42 DEG. 21. MIN. 42. SEC. N	87 DEG. 43. MIN. 42. SEC. W	97.	R13295
B 15	42 DEG. 54. MIN. 10. SEC. N	87 DEG. 44. MIN. 0. SEC. W	82.	R13093
B 17	43 DEG. 4. MIN. 56. SEC. N	87 DEG. 44. MIN. 40. SEC. W	198.	R13382
B 19	43 DEG. 15. MIN. 45. SEC. N	87 DEG. 44. MIN. 30. SEC. W	297.	R13099
B 21	43 DEG. 23. MIN. 54. SEC. N	87 DEG. 48. MIN. 12. SEC. W	200.	R13239
B 35	44 DEG. 42. MIN. 8. SEC. N	87 DEG. 45. MIN. 26. SEC. W	31.	R13223
B 36	44 DEG. 47. MIN. 36. SEC. N	87 DEG. 45. MIN. 30. SEC. W	46.	R13371
B 37	44 DEG. 53. MIN. 0. SEC. N	87 DEG. 45. MIN. 36. SEC. W	31.	R13057
C 6	42 DEG. 5. MIN. 33. SEC. N	87 DEG. 36. MIN. 17. SEC. W	56.	R13036
C 8	42 DEG. 16. MIN. 21. SEC. N	87 DEG. 36. MIN. 23. SEC. W	151.	R13086
C 10	42 DEG. 27. MIN. 6. SEC. N	87 DEG. 36. MIN. 54. SEC. W	246.	R13039
C 12	42 DEG. 38. MIN. 0. SEC. N	87 DEG. 36. MIN. 36. SEC. W	210.	R13303
C 14	42 DEG. 48. MIN. 56. SEC. N	87 DEG. 36. MIN. 36. SEC. W	151.	R13042
C 16	42 DEG. 59. MIN. 36. SEC. N	87 DEG. 36. MIN. 50. SEC. W	230.	R13309
C 18	43 DEG. 10. MIN. 20. SEC. N	87 DEG. 36. MIN. 54. SEC. W	302.	R13315
C 20	43 DEG. 21. MIN. 11. SEC. N	87 DEG. 37. MIN. 6. SEC. W	449.	R13046
C 22	43 DEG. 32. MIN. 0. SEC. N	87 DEG. 37. MIN. 6. SEC. W	384.	R13102
C 24	43 DEG. 42. MIN. 50. SEC. N	87 DEG. 37. MIN. 15. SEC. W	120.	R13049
C 26	43 DEG. 53. MIN. 36. SEC. N	87 DEG. 37. MIN. 20. SEC. W	151.	R13106
C 37	44 DEG. 53. MIN. 0. SEC. N	87 DEG. 38. MIN. 0. SEC. W	75.	R13219
D 3	41 DEG. 49. MIN. 45. SEC. N	87 DEG. 28. MIN. 48. SEC. W	46.	R13288
D 5	42 DEG. 0. MIN. 12. SEC. N	87 DEG. 28. MIN. 59. SEC. W	84.	R13290
D 7	42 DEG. 10. MIN. 56. SEC. N	87 DEG. 29. MIN. 0. SEC. W	170.	R13292
D 9	42 DEG. 21. MIN. 47. SEC. N	87 DEG. 29. MIN. 9. SEC. W	283.	R13296
D 11	42 DEG. 32. MIN. 36. SEC. N	87 DEG. 29. MIN. 14. SEC. W	312.	R13088
D 13	42 DEG. 43. MIN. 24. SEC. N	87 DEG. 29. MIN. 19. SEC. W	292.	R13090
D 15	42 DEG. 54. MIN. 15. SEC. N	87 DEG. 29. MIN. 30. SEC. W	322.	R13385
D 17	43 DEG. 5. MIN. 15. SEC. N	87 DEG. 29. MIN. 20. SEC. W	308.	R13097
D 19	43 DEG. 17. MIN. 50. SEC. N	87 DEG. 27. MIN. 45. SEC. W	276.	R13380
D 21	43 DEG. 26. MIN. 38. SEC. N	87 DEG. 29. MIN. 40. SEC. W	492.	R13240
D 23	43 DEG. 37. MIN. 6. SEC. N	87 DEG. 29. MIN. 45. SEC. W	464.	R13237
D 25	43 DEG. 48. MIN. 18. SEC. N	87 DEG. 29. MIN. 50. SEC. W	272.	R13326
D 27	43 DEG. 59. MIN. 0. SEC. N	87 DEG. 30. MIN. 0. SEC. W	203.	R13231
D 29	44 DEG. 9. MIN. 52. SEC. N	87 DEG. 30. MIN. 0. SEC. W	72.	R13053
D 38	44 DEG. 58. MIN. 30. SEC. N	87 DEG. 30. MIN. 30. SEC. W	97.	R13061
D 39	45 DEG. 3. MIN. 51. SEC. N	87 DEG. 30. MIN. 29. SEC. W	42.	R13121
D 40	45 DEG. 9. MIN. 51. SEC. N	87 DEG. 30. MIN. 32. SEC. W	46.	R13065
E 2	41 DEG. 43. MIN. 54. SEC. N	87 DEG. 21. MIN. 30. SEC. W	41.	R13032
E 4	41 DEG. 54. MIN. 48. SEC. N	87 DEG. 21. MIN. 50. SEC. W	95.	R13471
E 6	42 DEG. 5. MIN. 36. SEC. N	87 DEG. 21. MIN. 46. SEC. W	203.	R13475
E 8	42 DEG. 16. MIN. 25. SEC. N	87 DEG. 21. MIN. 48. SEC. W	289.	R13479
E 10	42 DEG. 27. MIN. 13. SEC. N	87 DEG. 21. MIN. 53. SEC. W	354.	R13483
E 12	42 DEG. 38. MIN. 2. SEC. N	87 DEG. 21. MIN. 50. SEC. W	397.	R13392
E 14	42 DEG. 48. MIN. 40. SEC. N	87 DEG. 22. MIN. 0. SEC. W	338.	R13307
E 16	42 DEG. 59. MIN. 38. SEC. N	87 DEG. 22. MIN. 5. SEC. W	305.	R13310
E 18	43 DEG. 10. MIN. 40. SEC. N	87 DEG. 21. MIN. 28. SEC. W	244.	R13316
E 20	43 DEG. 21. MIN. 20. SEC. N	87 DEG. 22. MIN. 15. SEC. W	318.	R13321
E 22	43 DEG. 32. MIN. 0. SEC. N	87 DEG. 22. MIN. 17. SEC. W	472.	R13323
E 26	43 DEG. 53. MIN. 40. SEC. N	87 DEG. 22. MIN. 33. SEC. W	259.	R13376
E 28	44 DEG. 5. MIN. 0. SEC. N	87 DEG. 22. MIN. 30. SEC. W	315.	R13109
E 30	44 DEG. 15. MIN. 18. SEC. N	87 DEG. 22. MIN. 30. SEC. W	236.	R13110
E 32	44 DEG. 31. MIN. 30. SEC. N	87 DEG. 15. MIN. 3. SEC. W	305.	R13113
E 34	44 DEG. 36. MIN. 53. SEC. N	87 DEG. 22. MIN. 41. SEC. W	102.	R13116
E 39	45 DEG. 3. MIN. 53. SEC. N	87 DEG. 22. MIN. 52. SEC. W	105.	R13369
E 40	45 DEG. 9. MIN. 17. SEC. N	87 DEG. 22. MIN. 54. SEC. W	72.	R13214
E 41	45 DEG. 14. MIN. 41. SEC. N	87 DEG. 22. MIN. 51. SEC. W	105.	R13126
F 1	41 DEG. 38. MIN. 30. SEC. N	87 DEG. 14. MIN. 21. SEC. W	48.	R13082
F 3	41 DEG. 49. MIN. 18. SEC. N	87 DEG. 14. MIN. 36. SEC. W	95.	R13083
F 5	42 DEG. 0. MIN. 20. SEC. N	87 DEG. 14. MIN. 30. SEC. W	171.	R13034
F 7	42 DEG. 10. MIN. 54. SEC. N	87 DEG. 14. MIN. 36. SEC. W	281.	R13477
F 9	42 DEG. 21. MIN. 56. SEC. N	87 DEG. 15. MIN. 50. SEC. W	420.	R13297
F 11	42 DEG. 32. MIN. 39. SEC. N	87 DEG. 14. MIN. 37. SEC. W	433.	R13485
F 13	42 DEG. 43. MIN. 27. SEC. N	87 DEG. 14. MIN. 42. SEC. W	472.	R13390
F 15	42 DEG. 54. MIN. 20. SEC. N	87 DEG. 14. MIN. 45. SEC. W	361.	R13094
F 17	43 DEG. 5. MIN. 5. SEC. N	87 DEG. 14. MIN. 58. SEC. W	266.	R13383
F 19	43 DEG. 15. MIN. 50. SEC. N	87 DEG. 14. MIN. 48. SEC. W	324.	R13100
F 21	43 DEG. 26. MIN. 42. SEC. N	87 DEG. 14. MIN. 48. SEC. W	279.	R13241
F 25	43 DEG. 48. MIN. 17. SEC. N	87 DEG. 14. MIN. 54. SEC. W	338.	R13235
F 27	43 DEG. 59. MIN. 5. SEC. N	87 DEG. 14. MIN. 58. SEC. W	341.	R13232
F 29	44 DEG. 10. MIN. 0. SEC. N	87 DEG. 15. MIN. 0. SEC. W	509.	R13229

Geol. no.	Latitude	Longitude	Depth (m)	Lab. no.
F 31	44 DEG. 20. MIN. 42. SEC. N	87 DEG. 15. MIN. 3. SEC. W	436.	R13227
F 35	44 DEG. 42. MIN. 18. SEC. N	87 DEG. 15. MIN. 9. SEC. W	154.	R13334
F 41	45 DEG. 14. MIN. 43. SEC. N	87 DEG. 15. MIN. 19. SEC. W	80.	R13362
F 42	45 DEG. 20. MIN. 7. SEC. N	87 DEG. 15. MIN. 19. SEC. W	107.	R13209
F 43	45 DEG. 25. MIN. 30. SEC. N	87 DEG. 15. MIN. 20. SEC. W	88.	R13355
F 44	45 DEG. 31. MIN. 0. SEC. N	87 DEG. 15. MIN. 30. SEC. W	48.	R13073
G 2	41 DEG. 44. MIN. 0. SEC. N	87 DEG. 7. MIN. 15. SEC. W	64.	R13287
G 4	41 DEG. 54. MIN. 46. SEC. N	87 DEG. 7. MIN. 20. SEC. W	144.	R13472
G 6	42 DEG. 5. MIN. 40. SEC. N	87 DEG. 7. MIN. 15. SEC. W	249.	R13085
G 8	42 DEG. 16. MIN. 25. SEC. N	87 DEG. 7. MIN. 18. SEC. W	349.	R13037
G 10	42 DEG. 27. MIN. 30. SEC. N	87 DEG. 7. MIN. 40. SEC. W	456.	R13300
G 12	42 DEG. 38. MIN. 0. SEC. N	87 DEG. 7. MIN. 19. SEC. W	489.	R13041
G 14	42 DEG. 47. MIN. 52. SEC. N	87 DEG. 7. MIN. 20. SEC. W	489.	R13388
G 16	42 DEG. 59. MIN. 40. SEC. N	87 DEG. 7. MIN. 22. SEC. W	262.	R13311
G 18	43 DEG. 10. MIN. 29. SEC. N	87 DEG. 7. MIN. 22. SEC. W	279.	R13317
G 20	43 DEG. 21. MIN. 17. SEC. N	87 DEG. 7. MIN. 24. SEC. W	157.	R13243
G 22	43 DEG. 32. MIN. 5. SEC. N	87 DEG. 7. MIN. 26. SEC. W	308.	R13324
G 24	43 DEG. 42. MIN. 54. SEC. N	87 DEG. 7. MIN. 27. SEC. W	495.	R13104
G 26	43 DEG. 53. MIN. 40. SEC. N	87 DEG. 7. MIN. 30. SEC. W	318.	R13107
G 28	44 DEG. 4. MIN. 30. SEC. N	87 DEG. 7. MIN. 30. SEC. W	472.	R13328
G 30	44 DEG. 15. MIN. 20. SEC. N	87 DEG. 7. MIN. 30. SEC. W	676.	R13330
G 32	44 DEG. 26. MIN. 7. SEC. N	87 DEG. 7. MIN. 31. SEC. W	778.	R13332
G 34	44 DEG. 36. MIN. 30. SEC. N	87 DEG. 7. MIN. 0. SEC. W	548.	R13057
G 36	44 DEG. 47. MIN. 43. SEC. N	87 DEG. 7. MIN. 35. SEC. W	312.	R13118
G 41	45 DEG. 14. MIN. 13. SEC. N	87 DEG. 7. MIN. 39. SEC. W	100.	R13066
G 42	45 DEG. 20. MIN. 6. SEC. N	87 DEG. 7. MIN. 40. SEC. W	90.	R13491
G 43	45 DEG. 25. MIN. 30. SEC. N	87 DEG. 7. MIN. 40. SEC. W	113.	R13360
G 44	45 DEG. 31. MIN. 0. SEC. N	87 DEG. 7. MIN. 42. SEC. W	72.	R13204
G 45	45 DEG. 36. MIN. 20. SEC. N	87 DEG. 7. MIN. 40. SEC. W	38.	R13508
H 3	41 DEG. 49. MIN. 18. SEC. N	87 DEG. 0. MIN. 0. SEC. W	107.	R13289
H 5	42 DEG. 0. MIN. 14. SEC. N	87 DEG. 0. MIN. 0. SEC. W	230.	R13473
H 7	42 DEG. 11. MIN. 0. SEC. N	87 DEG. 0. MIN. 0. SEC. W	310.	R13293
H 9	42 DEG. 21. MIN. 54. SEC. N	87 DEG. 0. MIN. 0. SEC. W	417.	R13087
H 11	42 DEG. 33. MIN. 0. SEC. N	87 DEG. 0. MIN. 30. SEC. W	508.	R13302
H 13	42 DEG. 43. MIN. 28. SEC. N	87 DEG. 0. MIN. 0. SEC. W	518.	R13092
H 15	42 DEG. 54. MIN. 16. SEC. N	87 DEG. 0. MIN. 0. SEC. W	328.	R13386
H 17	43 DEG. 5. MIN. 5. SEC. N	87 DEG. 0. MIN. 0. SEC. W	290.	R13044
H 19	43 DEG. 15. MIN. 53. SEC. N	87 DEG. 0. MIN. 0. SEC. W	335.	R13045
H 21	43 DEG. 26. MIN. 41. SEC. N	87 DEG. 0. MIN. 0. SEC. W	285.	R13047
H 23	43 DEG. 37. MIN. 30. SEC. N	87 DEG. 0. MIN. 0. SEC. W	407.	R13238
H 25	43 DEG. 47. MIN. 50. SEC. N	86 DEG. 59. MIN. 50. SEC. W	581.	R13051
H 27	43 DEG. 59. MIN. 0. SEC. N	87 DEG. 0. MIN. 0. SEC. W	361.	R13233
H 29	44 DEG. 10. MIN. 0. SEC. N	87 DEG. 0. MIN. 0. SEC. W	669.	R13375
H 31	44 DEG. 20. MIN. 43. SEC. N	87 DEG. 0. MIN. 0. SEC. W	764.	R13055
H 33	44 DEG. 31. MIN. 31. SEC. N	87 DEG. 0. MIN. 0. SEC. W	778.	R13226
H 35	44 DEG. 42. MIN. 19. SEC. N	87 DEG. 0. MIN. 0. SEC. W	604.	R13224
H 37	44 DEG. 53. MIN. 7. SEC. N	87 DEG. 0. MIN. 0. SEC. W	341.	R13220
H 39	45 DEG. 3. MIN. 55. SEC. N	87 DEG. 0. MIN. 0. SEC. W	154.	R13122
H 43	45 DEG. 25. MIN. 32. SEC. N	87 DEG. 0. MIN. 0. SEC. W	167.	R13071
H 45	45 DEG. 36. MIN. 20. SEC. N	87 DEG. 0. MIN. 0. SEC. W	66.	R13353
H 46	45 DEG. 41. MIN. 44. SEC. N	87 DEG. 0. MIN. 0. SEC. W	46.	R13077
I 4	41 DEG. 55. MIN. 30. SEC. N	86 DEG. 52. MIN. 36. SEC. W	156.	R13084
I 6	42 DEG. 5. MIN. 38. SEC. N	86 DEG. 52. MIN. 40. SEC. W	272.	R13476
I 8	42 DEG. 16. MIN. 25. SEC. N	86 DEG. 52. MIN. 43. SEC. W	402.	R13038
I 10	42 DEG. 27. MIN. 20. SEC. N	86 DEG. 52. MIN. 40. SEC. W	454.	R13301
I 12	42 DEG. 38. MIN. 0. SEC. N	86 DEG. 52. MIN. 40. SEC. W	515.	R13304
I 14	42 DEG. 48. MIN. 50. SEC. N	86 DEG. 52. MIN. 40. SEC. W	505.	R13308
I 16	42 DEG. 59. MIN. 40. SEC. N	86 DEG. 52. MIN. 38. SEC. W	320.	R13312
I 18	43 DEG. 11. MIN. 0. SEC. N	86 DEG. 53. MIN. 18. SEC. W	351.	R13319
I 20	43 DEG. 21. MIN. 17. SEC. N	86 DEG. 52. MIN. 36. SEC. W	397.	R13322
I 22	43 DEG. 32. MIN. 0. SEC. N	86 DEG. 52. MIN. 36. SEC. W	443.	R13325
I 24	43 DEG. 42. MIN. 34. SEC. N	86 DEG. 52. MIN. 30. SEC. W	459.	R13050
I 26	43 DEG. 53. MIN. 30. SEC. N	86 DEG. 52. MIN. 0. SEC. W	574.	R13377
I 28	44 DEG. 4. MIN. 30. SEC. N	86 DEG. 52. MIN. 30. SEC. W	471.	R13052
I 30	44 DEG. 15. MIN. 18. SEC. N	86 DEG. 52. MIN. 30. SEC. W	728.	R13111
I 32	44 DEG. 26. MIN. 10. SEC. N	86 DEG. 52. MIN. 30. SEC. W	823.	R13114
I 34	44 DEG. 37. MIN. 0. SEC. N	86 DEG. 52. MIN. 30. SEC. W	668.	R13372
I 36	44 DEG. 47. MIN. 43. SEC. N	86 DEG. 52. MIN. 25. SEC. W	674.	R13335
I 38	44 DEG. 58. MIN. 30. SEC. N	86 DEG. 53. MIN. 0. SEC. W	367.	R13062
I 40	45 DEG. 9. MIN. 12. SEC. N	86 DEG. 52. MIN. 22. SEC. W	207.	R13215
I 43	45 DEG. 25. MIN. 31. SEC. N	86 DEG. 52. MIN. 20. SEC. W	141.	R13361

Geol. no.	Latitude	Longitude	Depth (m)	Lab. no.
I 44	45 DEG. 30. MIN. 56. SEC. N	86 DEG. 52. MIN. 19. SEC. W	85.	R13205
I 45	45 DEG. 36. MIN. 20. SEC. N	86 DEG. 52. MIN. 20. SEC. W	43.	R13075
J 3	41 DEG. 49. MIN. 15. SEC. N	86 DEG. 45. MIN. 40. SEC. W	49.	R13033
J 5	42 DEG. 0. MIN. 13. SEC. N	86 DEG. 45. MIN. 26. SEC. W	170.	R13291
J 7	42 DEG. 11. MIN. 0. SEC. N	86 DEG. 45. MIN. 26. SEC. W	277.	R13478
J 9	42 DEG. 21. MIN. 48. SEC. N	86 DEG. 45. MIN. 24. SEC. W	295.	R13298
J 11	42 DEG. 32. MIN. 34. SEC. N	86 DEG. 45. MIN. 18. SEC. W	326.	R13486
J 13	42 DEG. 43. MIN. 30. SEC. N	86 DEG. 45. MIN. 20. SEC. W	404.	R13306
J 15	42 DEG. 54. MIN. 12. SEC. N	86 DEG. 45. MIN. 18. SEC. W	315.	R13387
J 17	43 DEG. 4. MIN. 40. SEC. N	86 DEG. 45. MIN. 0. SEC. W	364.	R13384
J 19	43 DEG. 15. MIN. 52. SEC. N	86 DEG. 45. MIN. 13. SEC. W	385.	R13381
J 21	43 DEG. 26. MIN. 36. SEC. N	86 DEG. 45. MIN. 30. SEC. W	433.	R13242
J 23	43 DEG. 37. MIN. 30. SEC. N	86 DEG. 45. MIN. 0. SEC. W	367.	R13378
J 25	43 DEG. 48. MIN. 16. SEC. N	86 DEG. 45. MIN. 6. SEC. W	449.	R13327
J 27	43 DEG. 59. MIN. 0. SEC. N	86 DEG. 45. MIN. 15. SEC. W	459.	R13234
J 29	44 DEG. 9. MIN. 54. SEC. N	86 DEG. 44. MIN. 59. SEC. W	568.	R13230
J 31	44 DEG. 20. MIN. 40. SEC. N	86 DEG. 45. MIN. 0. SEC. W	748.	R13228
J 33	44 DEG. 31. MIN. 30. SEC. N	86 DEG. 44. MIN. 56. SEC. W	810.	R13487
J 35	44 DEG. 42. MIN. 18. SEC. N	86 DEG. 44. MIN. 51. SEC. W	905.	R13059
J 37	44 DEG. 53. MIN. 0. SEC. N	86 DEG. 44. MIN. 50. SEC. W	689.	R13370
J 39	45 DEG. 3. MIN. 54. SEC. N	86 DEG. 44. MIN. 45. SEC. W	568.	R13367
J 41	45 DEG. 14. MIN. 40. SEC. N	86 DEG. 44. MIN. 40. SEC. W	182.	R13067
J 44	45 DEG. 31. MIN. 0. SEC. N	86 DEG. 44. MIN. 40. SEC. W	110.	R13506
J 46	45 DEG. 41. MIN. 45. SEC. N	86 DEG. 44. MIN. 36. SEC. W	49.	R13200
K 4	41 DEG. 55. MIN. 6. SEC. N	86 DEG. 38. MIN. 40. SEC. W	61.	R13474
K 6	42 DEG. 5. MIN. 36. SEC. N	86 DEG. 38. MIN. 14. SEC. W	115.	R13035
K 8	42 DEG. 16. MIN. 24. SEC. N	86 DEG. 38. MIN. 12. SEC. W	180.	R13481
K 10	42 DEG. 27. MIN. 2. SEC. N	86 DEG. 38. MIN. 1. SEC. W	251.	R13484
K 12	42 DEG. 37. MIN. 50. SEC. N	86 DEG. 37. MIN. 56. SEC. W	310.	R13393
K 14	42 DEG. 48. MIN. 50. SEC. N	86 DEG. 38. MIN. 0. SEC. W	289.	R13389
K 16	42 DEG. 59. MIN. 36. SEC. N	86 DEG. 36. MIN. 6. SEC. W	323.	R13313
K 18	43 DEG. 10. MIN. 24. SEC. N	86 DEG. 37. MIN. 48. SEC. W	361.	R13318
K 20	43 DEG. 21. MIN. 15. SEC. N	86 DEG. 37. MIN. 42. SEC. W	344.	R13379
K 22	43 DEG. 31. MIN. 56. SEC. N	86 DEG. 37. MIN. 36. SEC. W	269.	R13103
K 24	43 DEG. 42. MIN. 56. SEC. N	86 DEG. 37. MIN. 40. SEC. W	266.	R13105
K 26	43 DEG. 53. MIN. 39. SEC. N	86 DEG. 37. MIN. 36. SEC. W	200.	R13108
K 28	44 DEG. 4. MIN. 30. SEC. N	86 DEG. 37. MIN. 30. SEC. W	436.	R13329
K 30	44 DEG. 15. MIN. 15. SEC. N	86 DEG. 37. MIN. 30. SEC. W	715.	R13331
K 32	44 DEG. 26. MIN. 0. SEC. N	86 DEG. 37. MIN. 24. SEC. W	751.	R13333
K 34	44 DEG. 36. MIN. 53. SEC. N	86 DEG. 37. MIN. 19. SEC. W	874.	R13117
K 36	44 DEG. 42. MIN. 40. SEC. N	86 DEG. 32. MIN. 15. SEC. W	751.	R13119
K 38	45 DEG. 1. MIN. 0. SEC. N	86 DEG. 40. MIN. 30. SEC. W	751.	R13498
K 40	45 DEG. 9. MIN. 20. SEC. N	86 DEG. 37. MIN. 10. SEC. W	486.	R13495
K 42	45 DEG. 20. MIN. 5. SEC. N	86 DEG. 37. MIN. 2. SEC. W	177.	R13210
K 43	45 DEG. 25. MIN. 29. SEC. N	86 DEG. 37. MIN. 0. SEC. W	179.	R13128
L 7	42 DEG. 10. MIN. 59. SEC. N	86 DEG. 30. MIN. 56. SEC. W	84.	R13294
L 9	42 DEG. 21. MIN. 47. SEC. N	86 DEG. 30. MIN. 51. SEC. W	167.	R13299
L 11	42 DEG. 32. MIN. 39. SEC. N	86 DEG. 30. MIN. 48. SEC. W	251.	R13089
L 13	42 DEG. 43. MIN. 36. SEC. N	86 DEG. 30. MIN. 50. SEC. W	281.	R13391
L 15	42 DEG. 54. MIN. 12. SEC. N	86 DEG. 45. MIN. 18. SEC. W	266.	R13095
L 17	43 DEG. 5. MIN. 0. SEC. N	86 DEG. 30. MIN. 30. SEC. W	312.	R13098
L 19	43 DEG. 15. MIN. 49. SEC. N	86 DEG. 36. MIN. 24. SEC. W	210.	R13101
L 21	43 DEG. 26. MIN. 24. SEC. N	86 DEG. 30. MIN. 36. SEC. W	121.	R13048
L 25	43 DEG. 48. MIN. 14. SEC. N	86 DEG. 30. MIN. 10. SEC. W	115.	R13236
L 29	44 DEG. 9. MIN. 48. SEC. N	86 DEG. 29. MIN. 50. SEC. W	417.	R13054
L 31	44 DEG. 20. MIN. 36. SEC. N	86 DEG. 29. MIN. 53. SEC. W	656.	R13374
L 33	44 DEG. 31. MIN. 30. SEC. N	86 DEG. 29. MIN. 50. SEC. W	630.	R13056
L 35	44 DEG. 42. MIN. 15. SEC. N	86 DEG. 29. MIN. 40. SEC. W	481.	R13225
L 37	44 DEG. 53. MIN. 3. SEC. N	86 DEG. 29. MIN. 31. SEC. W	673.	R13221
L 39	45 DEG. 3. MIN. 50. SEC. N	86 DEG. 29. MIN. 30. SEC. W	650.	R13123
L 41	45 DEG. 14. MIN. 40. SEC. N	86 DEG. 29. MIN. 25. SEC. W	508.	R13363
L 43	45 DEG. 25. MIN. 28. SEC. N	86 DEG. 29. MIN. 19. SEC. W	379.	R13359
L 44	45 DEG. 30. MIN. 52. SEC. N	86 DEG. 29. MIN. 16. SEC. W	312.	R13074
L 45	45 DEG. 36. MIN. 12. SEC. N	86 DEG. 29. MIN. 13. SEC. W	190.	R13507
M 8	42 DEG. 16. MIN. 22. SEC. N	86 DEG. 23. MIN. 30. SEC. W	71.	R13482
M 10	42 DEG. 27. MIN. 8. SEC. N	86 DEG. 23. MIN. 30. SEC. W	158.	R13040
M 12	42 DEG. 37. MIN. 48. SEC. N	86 DEG. 23. MIN. 24. SEC. W	223.	R13305
M 14	42 DEG. 48. MIN. 50. SEC. N	86 DEG. 23. MIN. 40. SEC. W	240.	R13043
M 16	42 DEG. 59. MIN. 30. SEC. N	86 DEG. 23. MIN. 12. SEC. W	233.	R13314
M 18	43 DEG. 10. MIN. 23. SEC. N	86 DEG. 23. MIN. 5. SEC. W	121.	R13320
M 30	44 DEG. 15. MIN. 15. SEC. N	86 DEG. 22. MIN. 18. SEC. W	41.	R13112
M 32	44 DEG. 24. MIN. 0. SEC. N	86 DEG. 22. MIN. 6. SEC. W	433.	R13115

Geol. no.	Latitude	Longitude	Depth (m)	Lab. no.
M 34	44 DEG. 36. MIN. 50. SEC. N	86 DEG. 22. MIN. 15. SEC. W	653.	R13373
M 36	44 DEG. 47. MIN. 36. SEC. N	86 DEG. 22. MIN. 6. SEC. W	472.	R13336
M 38	44 DEG. 58. MIN. 30. SEC. N	86 DEG. 22. MIN. 0. SEC. W	535.	R13063
M 40	45 DEG. 9. MIN. 13. SEC. N	86 DEG. 21. MIN. 50. SEC. W	679.	R13216
M 42	45 DEG. 20. MIN. 0. SEC. N	86 DEG. 21. MIN. 42. SEC. W	584.	R13069
M 44	45 DEG. 30. MIN. 49. SEC. N	86 DEG. 21. MIN. 36. SEC. W	445.	R13505
M 46	45 DEG. 41. MIN. 40. SEC. N	86 DEG. 21. MIN. 30. SEC. W	185.	R13201
N 13	42 DEG. 43. MIN. 18. SEC. N	86 DEG. 16. MIN. 6. SEC. W	87.	R13091
N 15	42 DEG. 54. MIN. 12. SEC. N	86 DEG. 15. MIN. 54. SEC. W	89.	R13096
N 37	44 DEG. 53. MIN. 0. SEC. N	86 DEG. 14. MIN. 30. SEC. W	407.	R13222
N 39	45 DEG. 3. MIN. 46. SEC. N	86 DEG. 14. MIN. 16. SEC. W	302.	R13124
N 41	45 DEG. 14. MIN. 36. SEC. N	86 DEG. 14. MIN. 10. SEC. W	492.	R13494
N 43	45 DEG. 25. MIN. 22. SEC. N	86 DEG. 14. MIN. 0. SEC. W	522.	R13129
N 45	45 DEG. 36. MIN. 10. SEC. N	86 DEG. 13. MIN. 50. SEC. W	384.	R13352
N 47	45 DEG. 47. MIN. 0. SEC. N	86 DEG. 13. MIN. 40. SEC. W	138.	R13347
O 36	44 DEG. 47. MIN. 30. SEC. N	86 DEG. 6. MIN. 58. SEC. W	52.	R13120
O 38	44 DEG. 58. MIN. 19. SEC. N	86 DEG. 6. MIN. 54. SEC. W	210.	R13499
O 39	45 DEG. 3. MIN. 43. SEC. N	86 DEG. 6. MIN. 39. SEC. W	80.	R13125
O 40	45 DEG. 9. MIN. 10. SEC. N	86 DEG. 6. MIN. 30. SEC. W	387.	R13496
O 42	45 DEG. 19. MIN. 56. SEC. N	86 DEG. 6. MIN. 24. SEC. W	469.	R13211
O 44	45 DEG. 30. MIN. 40. SEC. N	86 DEG. 6. MIN. 15. SEC. W	354.	R13206
O 46	45 DEG. 41. MIN. 24. SEC. N	86 DEG. 5. MIN. 54. SEC. W	367.	R13078
O 48	45 DEG. 52. MIN. 19. SEC. N	86 DEG. 5. MIN. 53. SEC. W	85.	R13079
P 38	44 DEG. 58. MIN. 15. SEC. N	85 DEG. 59. MIN. 6. SEC. W	164.	R13488
P 41	45 DEG. 14. MIN. 30. SEC. N	85 DEG. 58. MIN. 58. SEC. W	502.	R13364
P 43	45 DEG. 25. MIN. 15. SEC. N	85 DEG. 58. MIN. 40. SEC. W	456.	R13358
P 47	45 DEG. 46. MIN. 48. SEC. N	85 DEG. 58. MIN. 0. SEC. W	171.	R13348
Q 38	44 DEG. 58. MIN. 15. SEC. N	85 DEG. 51. MIN. 30. SEC. W	103.	R13497
Q 39	45 DEG. 3. MIN. 36. SEC. N	85 DEG. 51. MIN. 28. SEC. W	151.	R13368
Q 40	45 DEG. 9. MIN. 0. SEC. N	85 DEG. 51. MIN. 20. SEC. W	251.	R13217
Q 41	45 DEG. 14. MIN. 28. SEC. N	85 DEG. 51. MIN. 38. SEC. W	177.	R13068
Q 42	45 DEG. 19. MIN. 50. SEC. N	85 DEG. 51. MIN. 0. SEC. W	36.	R13492
Q 44	45 DEG. 30. MIN. 35. SEC. N	85 DEG. 50. MIN. 52. SEC. W	272.	R13504
Q 48	45 DEG. 52. MIN. 11. SEC. N	85 DEG. 50. MIN. 26. SEC. W	157.	R13196
R 41	45 DEG. 14. MIN. 20. SEC. N	85 DEG. 43. MIN. 30. SEC. W	335.	R13365
R 42	45 DEG. 19. MIN. 40. SEC. N	85 DEG. 43. MIN. 30. SEC. W	492.	R13493
R 43	45 DEG. 25. MIN. 0. SEC. N	85 DEG. 43. MIN. 20. SEC. W	430.	R13130
R 44	45 DEG. 30. MIN. 0. SEC. N	85 DEG. 43. MIN. 12. SEC. W	110.	R13503
R 45	45 DEG. 36. MIN. 0. SEC. N	85 DEG. 43. MIN. 6. SEC. W	240.	R13076
S 38	45 DEG. 0. MIN. 0. SEC. N	85 DEG. 33. MIN. 0. SEC. W	351.	R13489
S 41	45 DEG. 14. MIN. 15. SEC. N	85 DEG. 36. MIN. 0. SEC. W	433.	R13366
S 42	45 DEG. 19. MIN. 24. SEC. N	85 DEG. 36. MIN. 0. SEC. W	185.	R13212
S 43	45 DEG. 25. MIN. 0. SEC. N	85 DEG. 35. MIN. 40. SEC. W	346.	R13357
S 44	45 DEG. 30. MIN. 35. SEC. N	85 DEG. 35. MIN. 30. SEC. W	259.	R13207
S 48	45 DEG. 52. MIN. 0. SEC. N	85 DEG. 35. MIN. 0. SEC. W	43.	R13197
T 38	45 DEG. 0. MIN. 0. SEC. N	85 DEG. 25. MIN. 30. SEC. W	157.	R13490
T 39	45 DEG. 3. MIN. 19. SEC. N	85 DEG. 28. MIN. 34. SEC. W	112.	R13064
T 40	45 DEG. 8. MIN. 43. SEC. N	85 DEG. 28. MIN. 30. SEC. W	451.	R13218
T 41	45 DEG. 14. MIN, 7. SEC. N	85 DEG. 28. MIN. 16. SEC. W	157.	R13127
T 42	45 DEG. 19. MIN. 31. SEC. N	85 DEG. 28. MIN. 6. SEC. W	299.	R13070
T 43	45 DEG. 24. MIN. 56. SEC. N	85 DEG. 28. MIN. 0. SEC. W	381.	R13500
T 44	45 DEG. 30. MIN. 19. SEC. N	85 DEG. 27. MIN. 50. SEC. W	180.	R13502
T 45	45 DEG. 35. MIN. 43. SEC. N	85 DEG. 27. MIN. 41. SEC. W	315.	R13351
T 48	45 DEG. 52. MIN. 0. SEC. N	85 DEG. 27. MIN. 15. SEC. W	66.	R13346
T 50	46 DEG. 2. MIN. 36. SEC. N	85 DEG. 26. MIN. 54. SEC. W	62.	R13081
U 42	45 DEG. 19. MIN. 26. SEC. N	85 DEG. 20. MIN. 30. SEC. W	272.	R13213
U 43	45 DEG. 24. MIN. 50. SEC. N	85 DEG. 20. MIN. 20. SEC. W	153.	R13131
U 44	45 DEG. 30. MIN. 15. SEC. N	85 DEG. 20. MIN. 12. SEC. W	236.	R13208
U 45	45 DEG. 35. MIN. 36. SEC. N	85 DEG. 20. MIN. 0. SEC. W	112.	R13350
U 46	45 DEG. 41. MIN. 0. SEC. N	85 DEG. 19. MIN. 48. SEC. W	108.	R13202
U 48	45 DEG. 51. MIN. 50. SEC. N	85 DEG. 19. MIN. 30. SEC. W	84.	R13198
U 49	45 DEG. 57. MIN. 24. SEC. N	85 DEG. 19. MIN. 10. SEC. W	33.	R13344
U 50	46 DEG. 2. MIN. 30. SEC. N	85 DEG. 19. MIN. 15. SEC. W	49.	R13194
V 43	45 DEG. 24. MIN. 40. SEC. N	85 DEG. 12. MIN. 40. SEC. W	218.	R13072
V 44	45 DEG. 30. MIN. 0. SEC. N	85 DEG. 12. MIN. 30. SEC. W	164.	R13501
V 45	45 DEG. 35. MIN. 29. SEC. N	85 DEG. 12. MIN. 19. SEC. W	118.	R13349
V 48	45 DEG. 51. MIN. 41. SEC. N	85 DEG. 11. MIN. 47. SEC. W	115.	R13345
V 49	45 DEG. 57. MIN. 5. SEC. N	85 DEG. 11. MIN. 36. SEC. W	85.	R13195
W 43	45 DEG. 24. MIN. 36. SEC. N	85 DEG. 4. MIN. 50. SEC. W	166.	R13356
W 46	45 DEG. 40. MIN. 42. SEC. N	85 DEG. 5. MIN. 12. SEC. W	105.	R13203
W 48	45 DEG. 51. MIN. 30. SEC. N	85 DEG. 3. MIN. 52. SEC. W	121.	R13080
X 48	45 DEG. 51. MIN. 25. SEC. N	84 DEG. 56. MIN. 21. SEC. W	95.	R13199

APPENDIX 2

CHEMICAL AND PHYSICAL ANALYSES

Lab. no.	Geol. no.	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	MgO (%)	CaO (%)	Na_2O (%)	K_2O (%)	TiO_2 (%)	P_2O_5 (%)	MnO (%)	Total organic carbon (%)	S (%)
R13058	A 35	79.20	5.99	1.06	1.18	1.98	.75	2.71	.21	.09	.03	.32	.06
R13295	B 9	79.37	3.13	1.25	2.50	4.41	.48	.98	.11	.05	.11	1.09	.03
R13093	B 15	56.67	5.24	2.67	5.25	8.12	.70	1.57	.24	.13	.12	2.68	.11
R13382	B 17	68.32	5.39	1.85	4.57	6.12	.72	1.57	.22	.10	.09	1.61	.03
R13099	B 19	50.01	8.78	3.52	5.69	6.96	.80	2.45	.45	.31	.07	4.92	.08
R13239	B 21	73.31	4.76	1.06	2.69	4.58	1.08	1.56	.14	.02	.07	1.21	.01
R13223	B 35	58.06	7.59	2.62	3.27	5.19	.88	2.47	.49	.19	.05	4.33	.18
R13371	B 36	53.88	9.85	5.69	2.03	3.36	.52	2.83	.63	.24	.14	5.46	.25
R13060	B 37	94.73	2.52	.56	.59	.44	.35	1.26	.06	.01	.03	.13	.06
R13036	C 6	66.28	3.05	2.09	5.46	7.79	.45	.83	.20	.04	.08	1.98	.12
R13086	C 8	76.92	3.85	1.26	2.57	4.24	.70	1.21	.12	< .01	.10	1.91	.05
R13039	C 10	62.28	6.45	2.50	4.43	6.18	.65	1.79	.34	.14	.07	2.72	.08
R13303	C 12	78.05	4.37	1.31	2.66	4.14	.63	1.20	.15	.02	.08	.94	.06
R13042	C 14	81.83	2.96	.96	1.15	2.10	.55	.97	.11	.03	.20	.27	.06
R13309	C 16	75.11	6.25	2.25	2.00	3.11	.78	1.73	.32	.11	.11	.36	.05
R13315	C 18	64.87	7.73	2.89	3.45	5.44	.88	2.09	.43	.13	.15	2.06	.04
R13046	C 20	51.58	12.07	4.70	3.64	4.14	.65	3.14	.57	.29	.09	3.51	.08
R13102	C 22	74.45	6.52	1.98	1.78	2.69	.80	1.93	.25	.06	.05	.84	.02
R13049	C 24	69.12	4.59	1.51	3.75	5.94	.95	1.07	.16	.04	.06	1.48	.01
R13106	C 26	70.01	4.09	1.19	3.71	5.63	.80	1.37	.16	.04	.11	1.13	.02
R13219	C 37	54.49	7.55	4.00	1.65	2.64	.48	1.89	.46	.30	.16	7.33	.34
R13288	D 3	74.35	3.76	1.27	3.49	5.56	.58	1.18	.15	.05	.05	1.16	.07
R13290	D 5	82.33	3.19	1.53	2.17	3.42	.58	.90	.22	.05	.05	.21	.01
R13292	D 7	76.99	4.59	1.87	2.26	3.85	.68	1.46	.27	.05	.17	.73	.03
R13296	D 9	66.91	7.83	2.89	2.92	4.38	.78	2.07	.39	.09	.09	1.49	.04
R13088	D 11	66.24	6.48	2.57	2.55	4.05	.80	1.85	.34	.12	.09	1.67	.03
R13090	D 13	67.51	6.02	2.36	2.14	3.92	.80	1.84	.30	.14	.23	.79	.03
R13385	D 15	72.18	8.13	3.02	1.97	3.10	.72	2.19	.39	.09	.08	.64	.02
R13097	D 17	59.81	8.89	5.45	2.03	3.16	.80	2.65	.47	.47	.10	1.17	.04
R13380	D 19	82.16	6.18	2.09	1.26	2.15	1.12	1.82	.26	.12	.06	.40	.02
R13240	D 21	50.09	10.51	4.73	3.36	3.95	.68	2.71	.52	.33	.17	4.67	.11
R13237	D 23	49.46	10.04	4.46	3.62	4.85	.78	2.69	.54	.23	.10	4.26	.16
R13326	D 25	78.49	6.34	2.25	1.40	2.45	.98	2.01	.30	.09	.08	.28	.02
R13231	D 27	59.91	4.98	1.63	4.66	7.57	.78	1.58	.22	.13	.09	1.95	.06
R13053	D 29	71.75	14.60	.82	3.61	5.54	.75	1.20	.08	.03	.04	1.56	.01
R13061	D 38	50.61	8.89	5.40	2.18	2.68	.55	2.49	.54	.39	.42	7.33	.20
R13121	D 39	85.66	3.59	2.38	.38	1.00	.60	1.03	.11	.05	.19	.15	.01
R13065	D 40	73.84	3.36	10.04	.14	.68	.55	1.13	.15	.20	1.46	.27	< .01
R13032	E 2	73.46	4.22	3.87	3.04	5.19	.85	1.07	.42	.08	.13	1.03	.03
R13471	E 4	72.81	3.79	5.26	4.41	5.15	.59	1.34	.72	.11	.10	.82	.03
R13475	E 6	63.43	6.20	2.66	5.20	7.56	.59	1.84	.28	.19	.05	2.15	.08
R13479	E 8	68.32	7.45	2.84	3.39	4.67	.79	2.05	.38	.16	.10	1.16	.04
R13483	E 10	52.95	12.09	5.29	3.43	5.02	.69	3.19	.59	.31	.10	3.65	.09
R13392	E 12	50.58	11.08	4.93	3.55	5.90	.52	2.87	.57	.24	.41	4.38	.07
R13307	E 14	50.50	10.63	4.49	3.79	6.55	.68	2.63	.54	.32	.13	4.15	.08
R13310	E 16	44.74	11.83	4.81	3.74	5.27	.88	3.14	.61	.12	.09	.98	.01
R13316	E 18	86.81	4.61	1.11	.81	.99	.78	1.24	.13	.06	.11	.31	.01
R13321	E 20	69.66	8.50	3.13	1.65	2.47	.68	2.43	.40	.15	.08	1.32	.06
R13323	E 22	51.36	11.53	4.86	3.36	4.65	.78	2.90	.56	.27	.11	4.02	.09
R13376	E 26	70.05	6.63	2.80	2.64	4.91	.72	2.17	.33	.08	.08	.68	.02

Lab. no.	Geol. no.	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	MgO (%)	CaO (%)	Na_2O (%)	K_2O (%)	TiO_2 (%)	P_2O_5 (%)	MnO (%)	Total organic carbon (%)	S (%)
R13109	E 28	51.68	8.24	3.96	5.17	2.20	.70	6.98	.40	.39	.16	4.17	.06
R13110	E 30	73.72	4.40	.89	3.03	1.37	.70	4.59	.10	< .01	.06	.30	.05
R13113	E 32	72.86	5.14	1.46	3.12	1.59	.70	4.78	.19	.04	.10	.37	.05
R13116	E 34	84.45	3.09	.78	1.55	.96	.50	2.62	.04	.01	.04	.31	.05
R13369	E 39	50.23	8.07	5.67	1.70	3.03	.52	2.51	.52	.50	.50	7.73	.30
R13214	E 40	64.87	3.64	9.13	.12	1.18	.48	1.07	.17	.44	5.95	1.03	.04
R13126	E 41	60.14	10.27	3.66	1.87	2.18	1.00	2.96	.53	.35	.18	4.31	.11
R13082	F 1	86.89	2.15	1.42	.60	1.54	.40	.62	.13	< .01	.05	.05	.01
R13083	F 3	56.36	8.40	4.45	4.08	6.08	.60	2.60	.44	.15	.10	1.29	.28
R13034	F 5	76.27	5.52	1.80	2.94	4.36	.75	1.47	.23	.06	.13	.35	.01
R13477	F 7	72.29	10.20	3.50	2.21	3.45	.69	2.58	.43	.19	.12	1.13	.03
R13297	F 9	51.10	12.45	4.95	2.32	4.65	.58	2.99	.59	.37	.15	4.08	.11
R13485	F 11	53.65	14.15	5.87	3.23	3.94	.59	3.37	.61	.34	.17	3.27	.08
R13390	F 13	52.93	13.05	6.20	3.39	3.22	.62	3.49	.62	.51	.11	3.36	.11
R13094	F 15	49.81	8.03	3.24	3.37	11.30	.60	2.31	.37	.16	.12	1.69	.17
R13383	F 17	69.88	6.61	2.41	3.66	6.14	.72	1.98	.29	.12	.08	.55	.01
R13100	F 19	51.29	10.45	3.84	3.43	5.39	.80	2.62	.54	.26	.09	4.36	.09
R13241	F 21	79.43	5.13	1.76	1.20	1.44	.68	1.67	.18	.09	.07	.45	.02
R13235	F 25	52.09	8.53	3.90	4.72	8.24	.98	2.67	.48	.20	.08	1.15	.05
R13232	F 27	64.22	10.25	3.90	2.33	2.72	1.18	2.94	.55	.08	.08	.37	.01
R13229	F 29	57.26	9.97	4.07	3.30	3.98	.78	2.80	.47	.22	.15	2.19	.05
R13227	F 31	62.17	9.83	4.04	2.07	2.46	.88	3.01	.47	.17	.12	1.86	.03
R13334	F 35	80.79	4.29	1.02	1.89	3.36	.58	1.33	.09	.05	.08	1.02	.01
R13362	F 41	68.88	4.41	8.50	< .01	1.32	.42	1.33	.15	.33	4.99	7.77	.01
R13209	F 42	49.10	9.18	4.56	2.19	2.99	.78	2.70	.54	.37	.23	.47	.26
R13355	F 43	82.73	4.52	4.27	< .01	.66	.42	2.38	.22	.10	1.26	.12	.01
R13073	F 44	84.44	2.15	6.00	.41	1.35	.35	1.71	.08	.11	.17	.93	.01
R13287	G 2	49.74	12.22	4.02	4.68	7.04	.48	3.19	.54	.07	.06	2.00	.18
R13472	G 4	82.17	4.55	1.38	1.98	3.72	.59	1.40	.11	.08	.08	.28	.06
R13085	G 6	64.07	7.58	3.06	2.62	3.38	.80	2.36	.41	.21	.10	.91	.02
R13037	G 8	63.61	12.31	4.31	2.62	2.82	.75	3.07	.51	.17	.14	1.49	.03
R13300	G 10	49.64	11.73	5.20	2.52	5.50	.68	2.97	.55	.42	.49	4.27	.10
R13041	G 12	56.93	15.42	5.77	2.55	2.06	.65	3.74	.66	.33	.31	3.38	.04
R13388	G 14	49.03	11.54	5.04	3.18	7.48	.52	2.85	.53	.31	.13	3.82	.08
R13311	G 16	78.90	4.95	1.80	1.06	2.11	.78	1.41	.19	.04	.22	.24	.02
R13317	G 18	84.77	5.13	1.28	1.13	1.14	.68	1.76	.18	.05	.07	.26	.02
R13243	G 20	85.67	4.17	.85	.52	1.04	.98	1.36	.08	.02	.05	.20	.04
R13324	G 22	71.69	6.41	2.39	2.14	3.45	.68	1.92	.27	.07	.08	.60	.10
R13104	G 24	47.74	10.84	4.73	3.86	5.07	.60	2.65	.54	.28	.18	4.08	.11
R13107	G 26	61.20	7.75	2.54	3.81	5.99	.90	2.37	.37	.06	.09	.86	.05
R13328	G 28	65.99	9.39	3.53	2.41	3.96	.78	2.58	.44	.17	.09	.55	.03
R13330	G 30	53.70	11.35	4.97	2.96	3.22	.68	2.99	.50	.31	.15	3.91	.13
R13332	G 32	53.77	11.98	5.28	2.55	3.11	.68	3.16	.52	.33	.06	3.82	.08
R13057	G 34	64.05	11.53	5.07	2.46	2.85	.85	3.08	.49	.14	.13	1.82	.06
R13118	G 36	78.05	4.89	1.38	1.83	2.71	.70	1.55	.19	.04	.07	.26	.02
R13066	G 41	64.48	8.12	3.49	2.71	3.29	1.15	2.64	.45	.14	.30	1.83	.28
R13491	G 42	86.86	6.94	2.38	.02	.71	.59	3.21	.15	.13	1.05	.29	.01
R13360	G 43	52.95	9.51	4.94	2.51	3.92	.62	2.89	.50	.37	1.68	5.44	.2
R13204	G 44	82.40	3.37	5.43	.34	.43	.38	1.76	.23	.11	.75	.16	.03
R13508	G 45	91.23	3.87	1.74	.55	.29	.29	2.16	.25	.01	.05	.05	.06

Lab. no.	Geol. no.	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	MgO (%)	CaO (%)	Na_2O (%)	K_2O (%)	TiO_2 (%)	P_2O_5 (%)	MnO (%)	Total organic carbon (%)	S (%)
R13289	H 3	66.96	3.92	2.03	5.50	7.59	.58	1.38	.16	.08	.09	1.66	.03
R13473	H 5	49.81	9.41	3.70	5.96	8.06	.59	2.53	.48	.20	.08	5.07	.10
R13293	H 7	64.09	10.33	3.69	2.02	3.09	.78	2.75	.48	.18	.10	1.27	.02
R13087	H 9	49.62	8.66	3.71	3.35	11.93	.60	2.42	.37	.17	.08	1.25	.04
R13302	H 11	47.05	10.79	4.53	2.72	8.23	.58	2.71	.48	.28	.24	4.01	.07
R13092	H 13	49.78	10.19	5.92	2.93	4.87	.60	2.89	.51	.61	.38	4.41	.09
R13386	H 15	78.09	8.35	3.02	1.35	1.66	.62	2.33	.36	.13	.17	1.01	.03
R13044	H 17	73.66	6.78	2.22	2.37	4.01	.75	1.92	.25	.07	.06	.95	.01
R13045	H 19	70.69	9.84	4.10	2.20	2.30	.75	2.64	.40	.12	.07	.56	.05
R13047	H 21	88.02	4.80	1.17	.23	.97	.65	1.50	.12	.07	.60	.23	.01
R13238	H 23	80.50	4.71	1.41	1.34	1.88	.68	1.64	.16	.05	.06	.51	.02
R13051	H 25	51.09	11.91	5.00	3.56	4.21	.65	3.00	.59	.23	.13	3.87	.12
R13233	H 27	74.80	6.84	2.59	1.23	1.43	.88	2.43	.30	.16	.11	.46	.01
R13375	H 29	55.22	10.25	5.63	2.04	2.65	.62	3.09	.54	.39	.22	4.13	.10
R13055	H 31	73.96	5.28	1.57	2.36	3.58	.85	1.73	.26	.09	.23	3.69	.01
R13226	H 33	41.11	10.32	5.01	2.82	2.74	.68	2.92	.48	.32	.19	3.94	.07
R13224	H 35	50.98	10.89	4.60	3.46	3.57	.88	3.32	.54	.27	.09	3.50	.08
R13220	H 37	67.04	4.90	1.69	3.96	5.91	.68	1.60	.23	.04	.06	.29	.01
R13122	H 39	75.73	4.37	.95	2.84	4.49	.60	1.30	.11	.02	.07	.75	.05
R13071	H 43	61.87	8.31	8.10	2.21	2.69	.75	2.64	.44	.19	.86	1.89	.06
R13353	H 45	81.51	2.26	8.67	.56	.32	.22	1.21	.06	.10	.77	.20	.01
R13077	H 46	90.83	1.99	3.20	.22	.24	.25	.92	.09	.03	.06	.07	.01
R13084	I 4	47.47	5.29	2.22	7.68	11.17	.70	1.67	.23	.09	.09	4.45	.08
R13476	I 6	55.68	9.30	3.75	4.84	7.45	.59	2.38	.46	.20	.14	3.99	.07
R13038	I 8	47.09	11.49	4.30	4.29	7.84	.55	2.64	.51	.25	.08	3.90	.10
R13301	I 10	47.12	10.13	4.62	3.51	8.19	.58	2.64	.51	.29		4.43	.09
R13304	I 12	47.74	10.38	4.51	3.58	7.61	.58	2.77	.51	.24	.15	4.33	.09
R13308	I 14	47.17	10.74	4.77	3.79	6.90	.58	2.69	.52	.31	.24	4.37	.07
R13312	I 16	68.96	10.68	3.91	1.44	1.87	.88	2.83	.52	.15	.07	.54	.04
R13319	I 18	64.13	11.29	5.64	1.30	1.53	.58	3.02	.52	.33	.26	1.43	.03
R13322	I 20	49.60	11.76	5.35	3.54	5.67	.58	2.90	.59	.25	.20	4.72	.08
R13325	I 22	71.60	8.99	3.45	1.78	1.93	.68	2.58	.41	.16	.14	1.75	.03
R13050	I 24	73.24	7.60	2.60	1.56	2.09	.55	1.78	.29	.11	.11	1.54	.04
R13377	I 26	50.06	10.50	5.32	3.72	4.54	.52	2.93	.54	.27	.14	3.05	.11
R13052	I 28	83.71	5.90	1.73	1.03	1.20	.45	1.83	.19	.05	.09	1.97	.03
R13111	I 30	55.94	13.47	5.18	1.95	3.63	.80	1.42	.56	.26	.18	3.37	.04
R13114	I 32	51.63	11.23	4.82	2.27	2.84	.60	2.87	.46	.42	1.33	4.07	.06
R13372	I 34	75.09	7.49	3.07	1.21	1.68	.52	2.46	.33	.15	.16	2.47	.06
R13335	I 36	53.06	11.74	4.83	2.50	4.43	.58	3.11	.54	.24	.16	3.36	.14
R13062	I 38	66.36	5.77	2.00	3.87	5.67	.75	2.01	.24	.09	.08	1.14	.03
R13215	I 40	81.81	4.07	3.12	.32	1.58	.78	1.55	.57	.05	.18	.13	.02
R13361	I 43	69.91	4.92	1.97	3.34	6.72	.62	2.21	.20	.07	.06	1.42	.14
R13205	I 44	81.68	3.24	6.07	.98	.37	.38	1.67	.34	.18	.08	.09	.01
R13075	I 45	89.03	3.10	1.07	.47	.20	.35	1.67	.20	.01	.03	.04	.04
R13033	J 3	83.73	3.61	1.23	1.08	2.07	.85	1.35	.22	.01	.04	.09	.04
R13291	J 5	41.96	7.26	5.21	5.96	11.17	.48	1.89	.40	.16	.12	5.66	.20
R13478	J 7	71.99	5.54	2.15	3.28	5.52	.59	1.63	.24	.11	.09	2.60	.07
R13298	J 9	46.33	8.76	4.33	5.11	9.29	.58	2.27	.49	.23	.12	5.15	.10
R13486	J 11	64.40	10.03	5.41	2.45	3.39	.59	2.74	.48	.35	.22	1.55	.02
R13306	J 13	64.30	9.47	3.68	2.03	3.88	.58	2.41	.40	.21	.11	2.28	.07

Lab. no.	Geol. no.	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	MgO (%)	CaO (%)	Na_2O (%)	K_2O (%)	TiO_2 (%)	P_2O_5 (%)	MnO (%)	Total organic carbon (%)	S (%)
R13387	J 15	74.65	8.90	3.30	1.19	2.02	.62	2.49	.39	.14	.11	1.05	.06
R13384	J 17	54.81	11.81	4.95	3.57	4.50	.52	3.08	.59	.29	.22	3.46	.12
R13381	J 19	55.61	11.15	5.65	2.84	4.07	.52	3.01	.55	.41	.83	2.98	.08
R13242	J 21	49.97	10.65	4.81	4.05	5.13	.58	2.84	.58	.25	.18	4.32	.08
R13378	J 23	47.79	9.76	5.40	3.74	6.46	.42	2.69	.57	.25	.16	4.28	.16
R13327	J 25	61.31	9.64	4.27	2.45	3.58	.58	2.67	.48	.21	.17	1.54	.07
R13234	J 27	48.71	9.67	4.80	3.01	5.77	.68	2.63	.56	.28	.10	4.20	.10
R13230	J 29	56.10	9.43	4.13	2.80	3.44	.58	2.67	.45	.26	.24	3.49	.06
R13228	J 31	54.93	10.90	4.42	2.48	2.92	.68	3.05	.48	.22	.22	3.19	.08
R13487	J 33	56.46	14.25	7.35	1.74	1.94	.69	3.50	.56	.79	.54	3.88	.08
R13059	J 35	54.29	11.32	4.75	2.81	2.71	.75	2.97	.51	.28	.18	3.87	.08
R13370	J 37	54.72	11.30	5.23	3.10	3.45	.52	3.18	.53	.33	.81	3.75	.06
R13367	J 39	53.89	11.14	4.95	3.88	4.15	.62	3.31	.55	.24	.08	4.07	.08
R13067	J 41	90.12	3.99	.54	.45	.34	.55	1.99	.06	.01	.17	.16	.01
R13506	J 44	53.12	9.83	4.25	3.53	4.97	.69	2.70	.49	.34	.13	6.09	.19
R13200	J 46	86.44	2.61	1.47	.58	.74	.48	1.02	.07	.05	.03	.08	.02
R13474	K 4	76.34	5.53	2.82	2.75	4.82	.59	1.67	.56	.07	.07	.61	.03
R13035	K 6	45.32	5.00	2.85	8.80	13.60	.95	1.53	.24	.10	.09	4.50	.13
R13481	K 8	45.13	8.36	5.55	6.03	10.90	.59	2.10	.47	.14	.13	5.45	.17
R13484	K 10	46.66	10.60	5.29	4.70	9.24	.39	2.45	.53	.25	.14	5.19	.18
R13393	K 12	54.25	10.69	4.54	5.25	5.83	.52	2.92	.55	.23	.10	3.56	.08
R13389	K 14	72.99	6.98	2.76	2.37	3.68	.52	2.00	.32	.13	.09	1.49	.05
R13313	K 16	55.83	10.48	4.76	3.54	4.55	.58	2.82	.55	.34	.23	3.58	.03
R13318	K 18	52.64	10.82	5.09	3.53	4.62	.58	2.64	.56	.30	.38	3.67	.11
R13379	K 20	47.97	9.36	5.55	4.16	7.43	.42	2.58	.55	.24	.13	4.29	.13
R13103	K 22	46.23	9.05	4.90	4.99	7.79	.40	2.28	.51	.25	.15	4.35	.14
R13105	K 24	45.41	9.48	4.80	4.87	6.95	.50	2.34	.53	.12	.15	5.07	.13
R13108	K 26	82.39	3.48	.79	.93	1.33	.40	1.61	.09	< .01	.04	.19	.01
R13329	K 28	50.33	11.00	5.40	3.96	6.12	.58	2.78	.59	.26	.15	4.40	.13
R13331	K 30	60.25	10.92	4.36	1.63	2.88	.58	2.83	.46	.23	1.61	2.85	.05
R13333	K 32	56.45	12.63	5.05	2.44	2.73	.68	3.50	.56	.26	.14	3.15	.13
R13117	K 34	53.03	11.61	5.04	2.41	2.73	.60	2.88	.49	.39	.13	3.24	.07
R13119	K 36	52.04	11.32	4.59	3.24	4.05	.60	2.76	.49	.33	.20	3.79	.11
R13498	K 38	54.66	12.09	5.08	2.50	3.45	.49	3.09	.52	.31	.15	3.85	.10
R13495	K 40	52.28	10.73	6.42	3.77	4.82	.59	2.83	.52	.68	.08	3.54	.07
R13210	K 42	90.29	3.37	.47	.41	.30	.38	1.70	.06	.04	.18	.08	.04
R13128	K 43	66.79	6.27	1.73	3.57	5.89	.80	2.02	.21	.08	.21	.96	.06
R13294	L 7	85.93	3.24	1.00	.86	2.23	.48	1.18	.12	.01	.04	.29	.05
R13299	L 9	45.89	8.02	4.49	5.45	10.15	.58	2.07	.45	.17	.09	4.67	.11
R13089	L 11	47.61	8.24	4.69	5.17	7.86	.50	2.42	.50	.25	.10	4.43	.14
R13391	L 13	52.64	9.25	4.75	4.40	6.86	.52	2.46	.47	.24	.13	4.63	.07
R13095	L 15	55.94	7.94	3.96	4.03	6.17	.50	2.28	.44	.15	.12	2.72	.09
R13098	L 17	70.05	5.89	2.56	2.23	3.71	.50	1.74	.29	.14	.06	.93	.08
R13101	L 19	70.37	4.70	1.45	3.00	5.15	.60	1.43	.17	.04	.09	.96	.05
R13048	L 21	72.69	4.78	1.24	3.02	4.76	.75	1.76	.17	.05	.06	.62	.05
R13236	L 25	80.41	3.54	.84	1.40	2.27	.58	1.54	.09	.02	.08	.15	.01
R13054	L 29	49.08	9.50	4.74	4.58	7.60	.55	2.41	.49	.21	.12	3.96	.19
R13374	L 31	62.78	9.52	4.99	2.07	2.81	.52	2.89	.49	.25	.47	1.71	.03
R13056	L 33	53.16	11.26	4.78	3.39	3.80	.65	3.02	.54	.26	.52	2.51	.10
R13225	L 35	74.17	6.20	2.44	1.77	2.32	.68	2.02	.30	.10	.05	.25	.04

Lab. no.	Geol. no.	SiO$_2$ (%)	Al$_2$O$_3$ (%)	Fe$_2$O$_3$ (%)	MgO (%)	CaO (%)	Na$_2$O (%)	K$_2$O (%)	TiO$_2$ (%)	P$_2$O$_5$ (%)	MnO (%)	Total organic carbon (%)	S (%)
R13221	L 37	51.82	11.22	4.70	3.43	4.16	.78	3.24	.54	.23	.13	3.40	.10
R13123	L 39	51.16	10.96	4.74	3.49	4.74	.50	2.66	.48	.35	.21	3.70	.06
R13363	L 41	61.28	9.23	4.03	3.12	3.33	.62	3.19	.46	.14	.1	3.14	.08
R13359	L 43	79.55	4.88	1.56	1.13	4.21	.52	2.04	.20	.02	.04	.22	.01
R13074	L 44	68.98	5.94	1.65	2.58	5.90	.65	2.02	.23	.11	.08	1.32	.01
R13507	L 45	91.65	4.15	1.01	.94	1.02	.49	1.62	.10	< .01	.16	.15	.01
R13482	M 8	84.24	3.53	1.70	.96	2.69	.59	1.43	.27	.06	.03	.08	.02
R13040	M 10	45.83	6.09	3.67	6.94	11.81	.55	1.75	.36	.16	.11	2.72	.14
R13305	M 12	47.04	8.30	4.53	5.85	8.84	.58	2.17	.47	.21	.12	2.72	.17
R13043	M 14	44.28	8.91	5.50	5.13	9.16	.45	2.29	.49	.23	.15	2.88	.09
R13314	M 16	47.71	8.77	4.83	5.40	8.15	.48	2.24	.49	.16	.12	2.71	.13
R13320	M 18	71.47	5.35	1.54	3.07	5.33	.78	1.85	.18	.10	.05	.36	.02
R13112	M 30	93.19	2.36	.33	.55	1.08	.30	.59	.01	< .01	.02	.03	.01
R13115	M 32	52.88	8.49	3.48	4.42	2.39	.50	6.65	.44	.18	.09	2.56	.13
R13373	M 34	51.94	9.92	5.25	2.55	5.50	.42	2.66	.51	.31	.16	3.23	.13
R13336	M 36	49.12	10.44	5.13	3.85	6.70	.48	2.62	.50	.28	.16	3.24	.16
R13063	M 38	54.66	10.86	4.60	3.83	5.28	.65	2.63	.47	.23	.13	2.05	.10
R13216	M 40	52.30	4.07	4.94	3.13	1.58	.78	3.37	.57	.26	.13	2.74	.15
R13069	M 42	51.52	11.36	4.70	3.42	4.06	.85	2.95	.53	.28	.17	3.71	.13
R13505	M 44	55.12	11.70	4.34	3.96	5.21	.69	3.12	.52	.26	.07	3.19	.11
R13201	M 46	85.00	4.37	.99	.24	1.06	.68	1.72	.13	.04	.15	.19	.04
R13091	N 13	84.13	2.44	.79	.24	1.13	.40	.99	.13	< .01	.04	.13	.01
R13096	N 15	89.11	2.50	.78	.69	.71	.50	.75	.04	.04	.04	.06	.01
R13222	N 37	52.59	7.72	2.64	5.21	8.31	.68	2.35	.40	.17	.06	2.01	.12
R13124	N 39	60.42	6.95	2.34	3.39	8.53	.50	1.85	.29	.03	.05	.31	.02
R13494	N 41	52.82	13.01	5.26	4.17	4.59	.59	3.40	.56	.31	.16	2.99	.07
R13129	N 43	48.31	11.50	4.34	4.42	5.10	.60	2.91	.52	.30	.08	2.88	.08
R13352	N 45	58.95	8.79	4.23	3.19	4.85	.62	2.74	.45	.42	.06	2.38	.07
R13347	N 47	93.98	2.11	.98	.8	.50	.32	1.00	.04	.01	.11	.06	.01
R13120	O 36	80.46	3.02	.73	2.11	4.02	.60	.79	.05	.07	.02	.05	.01
R13499	O 38	84.41	3.19	.88	2.20	4.04	.39	1.53	.12	.01	.03	.59	.13
R13125	O 39	92.27	1.63	.29	.56	.62	.50	.65	.04	.01	.02	.04	.04
R13496	O 40	79.11	7.66	2.73	1.41	2.26	.49	2.25	.32	.09	.09	.73	.05
R13211	O 42	48.88	10.17	4.17	4.27	5.53	.68	2.85	.50	.17	.15	.55	.09
R13206	O 44	49.68	5.80	2.11	4.25	13.53	.58	1.88	.26	.14	.06	3.73	.12
R13078	O 46	52.40	10.25	3.48	4.43	5.42	.85	2.83	.50	.23	.07	3.61	.15
R13079	O 48	86.88	2.97	.83	.46	.20	.45	1.43	.17	.01	.03	.03	.01
R13488	P 38	86.31	3.04	.69	1.27	2.85	.39	1.29	.08	.01	.35	.17	.03
R13364	P 41	71.72	5.14	2.29	2.98	5.20	.62	2.15	.30	.10	.05	.45	.09
R13358	P 43	39.67	7.61	4.42	5.82	16.39	.42	2.39	.34	.21	.06	1.20	.07
R13348	P 47	86.78	3.98	1.38	.28	1.55	.52	1.68	.16	.05	.04	.15	.04
R13497	Q 38	86.85	3.39	.70	1.53	4.58	.39	1.45	.08	.02	.03	.19	.01
R13368	Q 39	90.07	2.84	1.01	.70	2.02	.32	1.21	.08	.01	.08	.28	.01
R13217	Q 40	83.26	3.73	1.24	.74	1.80	.48	1.36	.17	.02	.05	.22	.01
R13068	Q 41	72.81	4.78	.67	2.89	5.59	.85	2.14	.11	.01	.04	.22	.03
R13492	Q 42	83.86	6.82	2.12	1.53	.69	.69	3.41	.17	.10	.03	.05	.01
R13504	Q 44	83.30	4.79	.70	1.97	3.72	.49	2.13	.08	< .01	.03	.23	.01
R13196	Q 48	79.52	7.65	1.06	.95	1.97	.88	2.65	.16	.06	.06	.25	.01
R13365	R 41	51.35	8.33	3.14	5.15	7.81	.52	2.55	.41	.14	.05	8.25	.15
R13493	R 42	71.32	7.11	2.21	2.87	4.71	.69	2.38	.26	.16	.05	1.52	.13

Lab. no.	Geol. no.	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	MgO (%)	CaO (%)	Na_2O (%)	K_2O (%)	TiO_2 (%)	P_2O_5 (%)	MnO (%)	Total organic carbon (%)	S (%)
R13130	R 43	74.13	5.31	1.56	1.99	3.15	.60	1.61	.21	.15	.12	4.49	.09
R13503	R 44	93.09	2.18	.59	.43	1.29	.29	.86	.03	.01	.04	.20	.01
R13076	R 45	51.41	9.09	3.11	4.86	6.57	.95	2.59	.43	.17	.12	.86	.12
R13489	S 38	82.37	4.29	1.78	1.00	2.75	.49	1.55	.16	.07	.13	.59	.03
R13366	S 41	72.17	4.12	1.89	2.65	5.77	.52	1.72	.16	.05	.02	.20	.09
R13212	S 42	93.91	2.32	.47	.81	.64	.38	.84	.05	.05	.03	.41	.01
R13357	S 43	84.05	3.68	1.10	.76	2.02	.42	1.43	.11	.03	.05	.28	.07
R13207	S 44	86.46	3.66	.92	.25	1.31	.58	1.41	.11	.06	.06	.10	.16
R13197	S 48	84.79	2.49	.68	.83	2.25	.48	.94	.17	.03	.03	.33	.02
R13490	T 38	87.14	3.23	.82	.77	2.43	.39	1.27	.09	.01	.04	.09	.06
R13064	T 39	92.10	3.05	.40	.01	.32	.55	1.31	.02	.01	.03	.23	.01
R13218	T 40	80.52	4.57	1.60	.92	3.11	.58	1.51	.19	.05	.04	.19	.02
R13127	T 41	85.79	3.23	.53	.89	1.98	.40	1.12	.08	.03	.05	.23	.02
R13070	T 42	66.14	6.57	1.83	3.06	6.69	.95	1.95	.23	.06	.04	.17	.01
R13500	T 43	50.36	10.72	4.41	3.94	5.47	.59	2.67	.48	.34	.12	5.23	.17
R13502	T 44	93.37	2.95	.76	.57	.62	.49	1.13	.07	.09	.06	.16	.04
R13351	T 45	86.28	3.86	.99	.30	1.44	.52	1.33	.14	.06	.06	.14	.05
R13346	T 48	91.38	3.47	.73	.29	1.27	.62	1.56	.05	< .01	.02	.14	.01
R13081	T 50	63.95	7.34	2.20	3.06	5.25	1.25	2.71	.35	.06	.03	.17	.10
R13213	U 42	88.05	2.78	.55	.31	1.59	.48	1.06	.06	.02	.08	.12	.05
R13131	U 43	85.45	3.10	.82	.79	1.67	.50	.89	.07	.02	.34	.53	.04
R13208	U 44	78.06	4.68	1.51	.85	2.07	.68	1.80	.19	.10	.46	.10	.02
R13350	U 45	93.66	1.84	.54	< .01	.54	.32	.86	.02	.01			.02
R13202	U 46	85.98	2.63	2.32	.26	.62	.48	1.03	.06	.05	.24	.32	.02
R13198	U 48	85.67	4.33	1.38	.37	1.06	.68	1.66	.15	.06	.08	.05	.06
R13344	U 49	83.68	2.03	.79	1.88	4.49	.42	.74	.05	.01	.03	.15	.01
R13194	U 50	88.70	3.13	.56	1.12	.56	.48	1.53	.08	.04	.03	.15	.01
R13072	V 43	59.94	9.20	2.51	3.63	4.61	.95	2.59	.41	.13	.06	.24	.17
R13501	V 44	86.46	4.29	1.36	.36	1.52	.49	1.44	.13	.10	.23	.25	.04
R13349	V 45	91.45	2.36	2.48	.12	.72	.32	1.00	.04	.05	.21	.20	.01
R13345	V 48	86.12	5.48	1.22	.74	.93	.92	2.42	.18	.05	.05	.44	.05
R13195	V 49	77.53	6.67	1.34	1.05	2.23	1.08	2.81	.21	.11	.05	.44	.06
R13356	W 43	92.09	2.39	.38	.02	.48	.42	1.12	.04	< .01	.03	.14	.02
R13203	W 46	47.91	7.36	2.69	5.30	8.65	.78	2.27	.36	.21	.06	3.66	.14
R13080	W 48	67.96	8.50	1.72	2.60	3.91	1.05	3.02	.27	.10	.03	2.08	.07
R13199	X 48	83.92	4.60	.88	1.12	1.05	.68	1.97	.15	.08	.05	.27	.03

Lab. no.	Geol. no.	Cl (ppm)	Ag (ppm)	As (ppm)	Ba (ppm)	Be (ppm)	Br (ppm)	Cd (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)
R13058	A 35	184	.6	1.9	710	1	4	< .5	29	2.2	17	1.4	3
R13295	B 9	171	< .3	6.4	320		5	.5	29	9	22	.7	7
R13093	B 15	204	< .5	11	280	< 1	2	< .5	32	8	35	1.9	14
R13382	B 17	197	< .5	4	340		16	< .5	27	5.8	26	1	8
R13099	B 19	153	< .5	6.2	490	1.6	74	.5	17	16	59	4	84
R13239	B 21	214	< .5	3.5	300		6	< .5	30	5	18	1	5
R13223	B 35	215	.4	6	355		11	< .5	37	12	53	1.8	27
R13371	B 36	105	< .5	9	470		26	.5	69	11	71	3.5	33
R13060	B 37	161	< .9	1.4	310	< 1	1	< .5	11	1.8	9	.5	< 1
R13036	C 6	272	.4	5.8	210	< 1	3	< .5	30	3.3	19	1.1	2
R13086	C 8	195	< .3	2.8	310	< 1	8	< .5	22	6.4	22	.9	6
R13039	C 10	219	< .5	3.6	410	1.5	30	< .5	35	6.8	42	2.3	12
R13303	C 12	247	< .4	3	330		8	< .5	32	4.7	22	.9	6
R13042	C 14	224	.2	3.4	300	< 1	7	< .5	30	5.5	17	.5	4
R13309	C 16	207	< .5	6	340		7	< .5	43	9	36	1.4	9
R13315	C 18	229	< .5	4	420		9	< .5	56	9	45	1.8	28
R13046	C 20	177	< .5	8.3	700	2.2	72	< .5	84	13	67	6.1	23
R13102	C 22	155	.7	3.7	500	.9	14	< .5	34	6	31	2.1	12
R13049	C 24	269	.8	< 2	420	< 1	4	< .5	33	3.8	18	1	2
R13106	C 26	235	.5	3.3	380	< 1	10	< .5	21	5	17	.8	5
R13219	C 37	231	< .6	14	310		35	< .5	46	8.4	50	2.7	
R13288	D 3	277	.2	4	175		4	< .5	17	4.4	17	.7	3
R13290	D 5	197	< .5	2.6	320		3	< .5	24	3.2	24	.5	2
R13292	D 7	189	.6	4.3	480		8	< .5	39	7	25	1.1	8
R13296	D 9	174	< .4	7	550		26	< .5	43	8.6	51	2.4	16
R13088	D 11	133	< .5	4.7	350	1.5	28	< .5	38	7.1	37	2.1	20
R13090	D 13	137	< .5	6.7	427	1.4	18	< .5	50	12.4	31	2.2	15
R13385	D 15	139	< .6	6.1	490		16	< .5	42	9.5	46	2.5	17
R13097	D 17	134	< .5	18	620	1.7	50	< .5	68	11.3	60	4.5	18
R13380	D 19	125	< .5	8.5	375		25	< .5	34	5.4	29	1.6	10
R13240	D 21	200	.6	14	400		102	< .5	63	13	72	5.3	59
R13237	D 23	169	.6	10	450		90	1.5	74	15	76	5.4	53
R13326	D 25	118	< .5	4.5	470		7	1	43	7	32	1.5	11
R13231	D 27	331	< .4	2	370		17	< .5	30	6.5	26	1.2	8
R13053	D 29	264	< .5	3.6	400	< 1	7	< .5	25	3.2	10	1	1
R13061	D 38	165	< .9	11.4	480	1.8	72	.5	77	11	61	3.5	25
R13121	D 39	106	< .7	22	350	< 1	3	< .5	20	3.8	16	.8	3
R13065	D 40	79	< .9	122	154	1.2	4	< .5	37	11	26	1	4
R13032	E 2	178	.2	3.3	510	< 1	2	< .5	24	4	43	.7	2
R13471	E 4	174	< 1	25	280		2	< .5	23	11	24	1.1	6
R13475	E 6	210	< .6	4	380		21	< .5	31	7.6	39	1.9	8
R13479	E 8	137	< .6	6	490		28	< .5	45	8.3	45	2.4	18
R13483	E 10	101	< .5	10	610		71	< .5	66	14	74	5.5	38
R13392	E 12	198	.6	10	600		86	1.5	80	14	78	5.3	54
R13307	E 14	128	< 1	12	490		80	.5	65	13	86	5	49
R13310	E 16	104	.4	5.6	520		5	< .5	93	16	80	4	26
R13316	E 18	112	< .7	5.5	300		8	< .5	28	5	18	.8	6
R13321	E 20	147	< .7	6.6	540		34	< .5	62	10	53	3.5	26
R13323	E 22	178	< .5	11	590		76	1	69	13	78	5.1	55
R13376	E 26	162	< .7	4	450		17	.5	57	8.5	38	2.4	16

Lab. no.	Geol. no.	Cl (ppm)	Ag (ppm)	As (ppm)	Ba (ppm)	Be (ppm)	Br (ppm)	Cd (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)
R13109	E 28	178	< .5	15	470	1.8	70	< .5	66	10.2	58	3	34
R13110	E 30	283	< .5	2.2	325	< 1	9	< .5	26	4.3	17	.8	5
R13113	E 32	286	< .5	4.6	480	< 1	10	< .5	33	7.1	25	1	6
R13116	E 34	229	< .5	3.5	264	< 1	6	< .5	16	2.7	12	.5	2
R13369	E 39	182	< .4	26	574		86	1	69	13	83	3.2	42
R13214	E 40	89	< .5	153	7400		18	1.5	200	47	21	.7	10
R13126	E 41	119	< .2	7.5	610		91	< .5	57	10.8	67	3.8	24
R13082	F 1	110	.1	6.4	120	< 1	.8	< .5	21	4	16	.5	2
R13083	F 3	173	< .2	22	400	2.2	2	< .5	53	13.5	58	5.1	18
R13034	F 5	185	.3	3.2	590	1.1	7	< .5	42	5	20	1.4	2
R13477	F 7	96	< .7	6.3	490		24	< .5	56	11	53	3.4	24
R13297	F 9	190	< .6	14	680		72	1.5	80	18	81	5.6	57
R13485	F 11	94	.7	9	600		72	< .5	73	18	77	6	40
R13390	F 13	174	< .5	7	570		71	< .5	66	16	75	5.6	40
R13094	F 15	129	.3	8.5	660	1.7	31	< .5	61	14	37	4.5	27
R13383	F 17	188	< .5	5.2	400		5	< .5	37	7.3	33	1.6	10
R13100	F 19	140	1.4	10	520	2.4	102	1	70	12	76	5.4	55
R13241	F 21	139	< .3	4	285		7	< .5	30	5	22	1.6	8
R13235	F 25	131	< .4	15	420		14	< .5	72	12	52	3.1	21
R13232	F 27	107	< .5	3.5	470		12	< .5	82	13	54	3	23
R13229	F 29	166	.3	13	520		72	< .5	63	14	64	4.6	33
R13227	F 31	128	< .4	9	500		33	< .5	65	13	56	4.6	32
R13334	F 35	216	< .5	3	345		10	< .5	19	5	16	.7	4
R13362	F 41	80	< .5	140	4200		175	2.5	360	59	17	.8	11
R13209	F 42	175	< .6	20	470		141	1.5	66	13	66	4	50
R13355	F 43	80	< .6	47	1800		9	< .5	125	23	20	1	5
R13073	F 44	101	< .9	3.1	240	< 1	2	< .5	14	3.4	15	.5	1
R13287	G 2	118	.3	12	420		2	< .5	66	10	100	7	28
R13472	G 4	214	< .7	3	345		7	< .5	19	4.6	20	.9	5
R13085	G 6	125	< .5	8.5	500	1.9	23	< .5	47	10.2	50	3.6	18
R13037	G 8	140	< .5	7.6	640	2	31	< .5	48	12	60	4.4	23
R13300	G 10	181	.9	23	590		88	1.5	60	13	176	4	59
R13041	G 12	141	< .5	10	790	2.3	61	.5	68	15	70	6.4	25
R13388	G 14	130	.8	13	576		82	1.5	62	14	87	5.5	52
R13311	G 16	144	< .5	10	370		7	.5	40	13	30	1	8
R13317	G 18	115	< .7	4.5	380		9	< .5	32	4	24	1	6
R13243	G 20	179	< .3	2	280		5	< .5	18	2.5	11	.8	4
R13324	G 22	313	< .5	6	390		17	1	42	6.5	33	2	48
R13104	G 24	170	.7	14	510	2	107	1	73	13	90	6	62
R13107	G 26	166	< .5	5.7	550	< 1	11	< .5	58	16	47	2.2	14
R13328	G 28	131	< .6	7	510		36	< .5	63	11	61	2.9	26
R13330	G 30	206	< .5	10	460		74	1	59	13	80	4.4	52
R13332	G 32	144	< .5	12	550		73	1	66	15	86	5.5	53
R13057	G 34	192	< .9	9.4	570	2.1	38	< .5	.5	14	63	4	26
R13118	G 36	191	< .1	3	460	< 1	8	< .5	31	6.1	25	1.3	6
R13066	G 41	195	< .9	15.6	560	1.6	13	< .5	48	7.8	37	2.8	10
R13491	G 42	91	< .5	19	1330		6	.5	101	19	15	1	4
R13360	G 43	190	< .6	10	1020		118	1	102	22	65	3.4	30
R13204	G 44	97	.2	63	1000		5	< .5	49	12	16	.5	3
R13508	G 45	132	< .6	2.6	370		1	< .5	24	1.7	11	.7	2

Lab. no.	Geol. no.	Cl (ppm)	Ag (ppm)	As (ppm)	Ba (ppm)	Be (ppm)	Br (ppm)	Cd (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)
R13289	H 3	239	< .9	5.4	380		6	< .5	21	4.9	28	.8	6
R13473	H 5	143	.1	5	460		51	.5	61	11	70	4	41
R13293	H 7	113	< .4	7	700		24	< .5	74	15	62	5.3	25
R13087	H 9	87	< .3	11.3	500	2	15	< .5	62	12	56	4.6	23
R13302	H 11	134	.5	17	690		88	1.5	67	12	69	5	52
R13092	H 13	146	.5	33	710	1.9	89	1.5	60	16	71	5.7	18
R13386	H 15	100	.1	10	400		24	< .5	43	10	38	2.7	18
R13044	H 17	160	.2	4.1	500	1.2	7	< .5	40	4.7	27	2.1	4
R13045	H 19	357	< .5	7.7	670	1.7	14	< .5	60	10.4	41	3.6	13
R13047	H 21	130	< .5	9.3	450	< 1	10	1.5	54	16	10	1	3
R13238	H 23	140	< .4	3.4	280		14	< .5	30	4	20	1.5	12
R13051	H 25	187	.5	10.1	570	2.4	68	1	100	14	94	8.5	44
R13233	H 27	101	.3	5.6	470		11	< .5	60	11	37	2.9	14
R13375	H 29	152	.4	8.6	480		78	1.5	78	13	72	5.5	61
R13055	H 31	219	< .5	3.3	460	1.1	7	.5	42	4	20	1.4	48
R13226	H 33	114	< .4	14	530		71	1.5	69	15	76	6.3	57
R13224	H 35	147	< .4	7.6	520		88	.5	72	15	76	6.4	42
R13220	H 37	230	< .4	2	330		6	< .5	30	5.5	22	1.2	8
R13122	H 39	318	< .5	2	317	< 1	10	< .5	19	3.6	13	.8	4
R13071	H 43	109	< .9	25	153	1.9	11	.5	110	22	40	2.7	12
R13353	H 45	63	< .5	10	1200		3	< .5	26	10.6	17	.4	2
R13077	H 46	108	.2	46	255	< 1	2	< .5	17	2.4	3	.5	< 1
R13084	I 4	264	< .2	3	343	1.4	14	< .5	36	6.5	40	1.9	16
R13476	I 6	125	< .7	6.5	435		46	.5	41	11	57	3.3	34
R13038	I 8	151	.4	10	690	2.2	81	< .5	79	11	79	6	38
R13301	I 10	132	< .5	15	700		77	1.5	70	12	83	5	54
R13304	I 12	127	< .5	10	360		69	1.5	48	9.7	56	3.7	51
R13308	I 14	130	.5	14	470		75	1.5	64	14	87	5	53
R13312	I 16	139	< .5	5.4	550		10	< .5	87	12	60	3.4	24
R13319	I 18	106	< .6	19	530		27	< .5	67	14	72	5.1	35
R13322	I 20	138	< .7	13	470		78	1	71	14	91	5.8	56
R13325	I 22	95	< .5	6	410		24	< .5	43	7.4	39	2.8	24
R13050	I 24	112	< .5	6.3	570	1.9	40	< .5	54	8.1	40	3.2	22
R13377	I 26	103	< .5	14	470	2.5	60		67	13.6	88	5.6	30
R13052	I 28	91	< .5	3.6	450	1.4	22	< .5	33	4	23	1.7	9
R13111	I 30	99	.6	13	1100	2.4	64		92	20	93	6.9	32
R13114	I 32	92	< .5	19	600	2	86		75	16	91	6	45
R13372	I 34	143	< .5	5.7	444	1.7	37	.5	52	8	41	3.7	26
R13335	I 36	143	< .5	10	515		71	1	63	16	92	5.6	54
R13062	I 38	241	.4	3.6	473	1.1	19	< .5	37	4.9	21	1.5	5
R13215	I 40	132	< .4	7	450		54	< .5	72	14	58	7	4
R13361	I 43	262	< .7	10	540		105	< .5	30	5	23	1	5
R13205	I 44	65	.3	68	320		2	< .5	26	4	19	.7	2
R13075	I 45	204	< .9	65.5	430	< 1	3	< .5	23	1.2	9	.6	< 1
R13033	J 3	197	.3	2.2	590	< 1	3	< .5	22	3	30	.7	1
R13291	J 5	237	< .5	14	670		17	1.5	59	13	56	4.4	47
R13478	J 7	186	< 1	5.3	350		18	.5	30	5.5	38	1.9	21
R13298	J 9	148	.5	12	520		57	1	60	14	87	4	45
R13486	J 11	108	< .7	24	445		24	< .5	60	12.5	63	4.2	26
R13306	J 13	170	< .4	10	470		43	.5	54	11	65	4	31

Lab. no.	Geol. no.	Cl (ppm)	Ag (ppm)	As (ppm)	Ba (ppm)	Be (ppm)	Br (ppm)	Cd (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)
R13387	J 15	153	< .7	7.8	470		25	< .5	44	10	49	3.5	20
R13384	J 17	182	< .6	9	600		66	.5	65	14	75	5.3	39
R13381	J 19	155	< .5	38	560		55	.5	62	14	69	5.3	35
R13242	J 21	132	< .3	12	400		58	1	70	14	70	6	47
R13378	J 23	186	< .5	19	430		47	1.5	64	13.6	110	5.6	51
R13327	J 25	170	.3	12	470		48	< .5	61	14	77	4.3	23
R13234	J 27	171	.5	15	380		86	1	72	15	96	5.8	47
R13230	J 29	136	< .5	14	450		88	1	60	13	68	5.4	50
R13228	J 31	261	< .4	11	540		84	.5	68	15	70	6.2	47
R13487	J 33	143	< .4	26	780		57	1	68	18	76	5.7	59
R13059	J 35	129	< .9	12.4	590	2.2	84	1	73	13	79	6.1	45
R13370	J 37	91	< .4	15	600		64	1	65	13	79	5.5	56
R13367	J 39	104	< .4	6	530		71	.5	67	12	71	4.6	44
R13067	J 41	132	< .9	4.4	430	< 1	5	< .5	36	4	5	1	1
R13506	J 44	153	< .6	17	380		77	.5	48	9	56	2.5	33
R13200	J 46	94	< .5	9.3	220		3	< .5	19	2.2	11	.5	1
R13474	K 4	162	< .5	3	395		2	< .5	36	6	67	.9	3
R13035	K 6	282	.3	5	560	1.3	6	< .5	44	4.4	42	1.8	6
R13481	K 8	199	.9	16	370		28	1	47	11	121	3.8	42
R13484	K 10	179	.7	12	440		44	1.5	56	12	104	4.8	50
R13393	K 12	172	< .7	7.2	510		48	< .5	77	13	66	4.7	31
R13389	K 14	113	.2	8	420		34	< .5	40	7.6	47	2.7	18
R13313	K 16	115	< .5	13	430		44	.5	63	12	64	4.3	42
R13318	K 18	210	.9	21	510		58	.5	67	13	81	5.1	38
R13379	K 20	125	< .5	17	460		45	1	65	14	120	5.7	44
R13103	K 22	119	1.1	18	420	1.7	39	1.5	53	11.6	130	5.6	51
R13105	K 24	141	< .5	19	420	1.8	45	1.5	71	13	124	5.5	48
R13108	K 26	101	< .5	3.2	360	< 1	5	< .5	27	2.9	14	1.1	4
R13329	K 28	128	.7	12	470		49	1.5	65	15	113	5.5	49
R13331	K 30	90	< .5	11	525		74	.5	59	13	79	4.6	42
R13333	K 32	162	< .6	7.5	580		72	.5	66	16	78	5.2	41
R13117	K 34	115	< .5	16	550	2	83	< .5	67	16.7	92	6.5	42
R13119	K 36	179	< .2	12	400	< 1	74	1	65	13.4	81	6	52
R13498	K 38	112	.4	8.6	420		47	1	51	13	72	4.5	50
R13495	K 40	160	< .5	23	480		91	< .5	68	14	78	5.6	36
R13210	K 42	110	< .5	4	320		4	< .5	26	5	5	.5	3
R13128	K 43	275	< .2	7.6	547		16	< .5	52	12.4	25	1.5	7
R13294	L 7	203	.2	5	420		3	< .5	20	4	19	.7	4
R13299	L 9	178	.6	12	450		29	.5	58	10	111	3.6	32
R13089	L 11	191	< .3	13.7	454	2	54	1	52	12.6	106	5.1	42
R13391	L 13	109	.5	12	480		57	1	67	12	84	4.4	48
R13095	L 15	216	< .5	13	473	1.7	50	.5	53	10.5	76	5	30
R13098	L 17	171	< .5	7.3	420	1.2	37	< .5	39	7.5	53	3.2	14
R13101	L 19	206	< .5	4.5	440	< 1	8	< .5	37	5.4	31	1.8	7
R13048	L 21	270	< .5	5.2	500	1.0	3	< .5	26	3.7	15	1	2
R13236	L 25	138	< .3	3.5	330		6	< .5	20	3	12	.9	3
R13054	L 29	189	.7	13.6	520	2.1	43	1	84	11	97	7.2	40
R13374	L 31	135	< .6	17	570		34	.5	69	12	54	5	24
R13056	L 33	168	.7	9.1	590	2.3	59	< .5	50	14	75	7.2	39
R13225	L 35	157	< .4	4	310		7	< .5	37	6.5	28	2	11

Lab. no.	Geol. no.	Cl (ppm)	Ag (ppm)	As (ppm)	Ba (ppm)	Be (ppm)	Br (ppm)	Cd (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)
R13221	L 37	83	< .5	9	420		69	1	60	14	70	6.3	46
R13123	L 39	98	< .1	15	430	1.8	74	1.5	62	13	81	1.3	54
R13363	L 41	182	.15	7.5	650		107	.5	75	11	11	4.4	42
R13359	L 43	116	< .5	2.7	500		6	< .5	38	4.2	24	1.3	9
R13074	L 44	155	< .9	2.7	440	1.4	10	< .5	36	4.5	24	1.8	6
R13507	L 45	117	< .6	3.7	330		6	< .5	28	5.6	12	.6	3
R13482	M 8	122	< .5	2.2	400		3	< .5	26	3	31	.6	2
R13040	M 10	197	< .5	9.1	450	1.7	14	.5	47	7.1	80	3	20
R13305	M 12	194	< .6	13	400		29	1	57	11.7	114	4	41
R13043	M 14	190	.7	16.6	600	1.8	35	1	50	10	125	5.3	29
R13314	M 16	136	.7	12	370		28	1	57	11	111	4.3	43
R13320	M 18	189	< .6	6	400		7	< .5	29	4.5	26	1.2	5
R13112	M 30	83	< .7	1.2	300		1	.5	17	1	5	.5	1
R13115	M 32	111	< .5	13	430	1.8	45	< .5	61	12	93	4.6	38
R13373	M 34	139	.5	13	420		44	1	70	12	91	5.7	41
R13336	M 36	173	.9	15	440		50	1	62	12	100	5.5	48
R13063	M 38	187	.7	12.6	465	2.2	60	.5	69	7.4	86	7.7	37
R13216	M 40	178	< .5	4.3	350		54	< .5	52	8	28	1	35
R13069	M 42	174	.4	14.8	470	2.2	76	1	73	11	83	8.1	44
R13505	M 44	195	< .5	3.9	450		49	< .5	57	12	62	4	33
R13201	M 46	166	< .5	3	380		7	< .5	24	3.1	9	.7	4
R13091	N 13	98	.3	2.8	290	< 1	3	< .5	14	2.4	21	.5	2
R13096	N 15	101	< .5	2.8	254	< 1	1	< .5	15	2	8	.4	1
R13222	N 37	185	< .4	7	390		41	< .5	47	9	58	3.8	25
R13124	N 39	135	.4	4.8	360		6	< .5	48	8.2	37	3.4	12
R13494	N 41	118	< .5	6.3	525		51	.5	56	13	75	4.6	36
R13129	N 43	138	.2	4.2	454		34	< .5	62	14	85	6.4	37
R13352	N 45	128	< .6	10	490		66	< .5	52	8.9	56	3.2	27
R13347	N 47	75	< .6	5.7	310		2	< .5	17	4.7	6	.4	1
R13120	O 36	220	< .5	4.2	200	< 1	4	< .5	14	2.2	82	.5	1
R13499	O 38	224	< .4	2.4	320		5	< .5	18	2.5	12	.6	5
R13125	O 39	127	< .2	1.6	150		2	< .5	11	.84	3	.3	1
R13496	O 40	149	< .4	4	410		7	< .5	40	7.6	40	2.6	11
R13211	O 42	174	.4	8	450		75	1	64	13	69	6	55
R13206	O 44	151	< .4	4.4	280		17	< .5	47	7	31	2.8	14
R13078	O 46	210	< .9	7.2	480	2	78	.5	63	9.5	50	4.4	26
R13079	O 48	122	.2	2.3	410	< 1	2	< .5	18	1.3	9	.6	< 1
R13488	P 38	156	< .5	1.8	290		5	< .5	16	2	11	.6	2
R13364	P 41	150	< .5	6	480		43	< .5	38	4.6	43	1.7	9
R13358	P 43	116	< .4	14	430		19	< .5	61	9.1	51	4	20
R13348	P 47	174	< .6	1.8	350		6	< .5	25	2.2	15	.9	4
R13497	Q 38	160	< .5	1.4	290		4	< .5	17	1.7	11	.6	3
R13368	Q 39	110	.13	2.4	345		6	< .5	22	2.9	10	.7	3
R13217	Q 40	99	< .6	1.8	230		5	< .5	24	3	12	1.3	7
R13068	Q 41	175	< .9	1.1	530	< 1	8	< .5	15	2.6	7	1.1	1
R13492	Q 42	97	< .7	15	1140		19		77	14	14	1.2	
R13504	Q 44	176	< .4	1.4	460		7	< .5	17	1.6	10	.7	3
R13196	Q 48	145	.6	2.5	480		5	< .5	25	2.4	11	1	3
R13365	R 41	180	.4	6	430		58	< .5	55	8.5	58	3.5	22
R13493	R 42	234	< .5	4	370		34	< .5	29	5.2	33	2	18

Lab. no.	Geol. no.	Cl (ppm)	Ag (ppm)	As (ppm)	Ba (ppm)	Be (ppm)	Br (ppm)	Cd (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)
R13130	R 43	136	< .2	5.8	300		65	1	28	4	23	1.5	51
R13503	R 44	120	< .3	1.7	180		6	< .5	12	1.1	6	.4	4
R13076	R 45	186	< .9	4.3	520	1.9	79	1	58	9	48	4	25
R13489	S 38	129	< .5	6.3	290		19	< .5	24	3.7	21	1.2	14
R13366	S 41	203	< .4	2	400		17	< .5	23	3.7	17	1	8
R13212	S 42	148	< .3	2	210		7	< .5	17	1.7	7	.6	3
R13357	S 43	188	.5	3.8	370		12	< .5	26	2.4	15	.9	7
R13207	S 44	142	< .6	2.2	320		12	< .5	25	2.8	12	1	4
R13197	S 48	134	< .7	.8	200		2	< .5	15	1.2	6	.5	1
R13490	T 38	202	.1	2.1	250		11	< .5	16	2	11	.7	5
R13064	T 39	88	.3	1.5	403	< 1	3	< .5	13	.7	4	6.2	< 1
R13218	T 40	127	< .7	2	280		8	< .5	30	3	16	1.6	5
R13127	T 41	125	.1	1.4	308		7	< .5	16	1.8	8	.6	3
R13070	T 42	136	< .9	2.5	420	1.4	5	< .5	35	4.3	27	2.2	3
R13500	T 43	145	.4	12	420		84	1	50	12	69	4.2	56
R13502	T 44	145	.2	< 1.9	240		5	< .5	16	2.1	10	.6	4
R13351	T 45	142	< .6	1.9	320		5	< .5	19	2.3	14	.6	5
R13346	T 48	114	< .5	3.4	380		3	< .5	15	1.2	10	.6	2
R13081	T 50	262	< .9	4.2	640	1.4	17	< .5	37	3.6	33	1.4	7
R13213	U 42	185	< .4	2	270		8	< .5	16	2.3	8	.6	4
R13131	U 43	180	< .2	5.7	256		6	< .5	15	5.3	8	.5	4
R13208	U 44	107	< .5	6.5	450		19	1	50	12	23	1.5	9
R13350	U 45	101	< .5	2.2	170		5	< .5	11	1	5	.3	1
R13202	U 46	125	< .3	21	400		9	< .5	24	6.8	9	.6	4
R13198	U 48	164	< .4	6.1	450		8	< .5	29	3.9	15	1	2
R13344	U 49	210	< .5	1.4	190		3	< .5	11	1.1	7	.2	2
R13194	U 50	85	< .7	1.7	420		3	< .5	20	1.1	7	.6	1
R13072	V 43	239	< .9	4.8	420	1.7	61	< .5	47	7.9	39	3	19
R13501	V 44	126	< .5	3.6	345		8	< .5	28	5.8	9	.6	4
R13349	V 45	121	< .7	19	450		7	< .5	20	6.4	12	.5	2
R13345	V 48	144	< .5	1.7	610		18	< .5	27	2.9	17	.8	4
R13195	V 49	158	< .7	4.3	590		11	< .5	29	3.1	19	1.2	5
R13356	W 43	78	< .4	1.8	370		4	< .5	14	1.1	8	.5	2
R13203	W 46	226	< .3	6	380		65	.5	56	8.2	50	3.2	29
R13080	W 48	216	< .9	3	740	1.5	24	< .5	18	4.4	33	2.1	12
R13199	X 48	108	< .5	2	470		4	< .5	25	2.3	11	.9	3

Lab. no.	Geol. no.	Eu (ppm)	Ga (ppm)	Hf (ppm)	Hg (ppm)	La (ppm)	Lu (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Rb (ppm)	Sb (ppm)	Sc (ppm)
R13058	A 35	.5	6.1	9	.12	11	.2	< .8	4	4	80	1	2.8
R13295	B 9	.4	3	2.6	.05	12	.2	<10	12	24	30	.4	2.6
R13093	B 15	.6	6.2	2.8	.03	19	.2	< 8	11	14	50	.4	6.2
R13382	B 17	.5	7	3.7	.04	14	.1	<10	11	12	45	.4	4
R13099	B 19	.9	14.5	5.3	.09	32	.3	< 5	27	83	90	2.6	8.6
R13239	B 21	.5	7	4	.03	15	.2	<26	9	10	60	.3	3.4
R13223	B 35	.9	13	6	.83	27	.3	<20	15	53	72	1.2	6.5
R13371	B 36	1	13	6	.34	31	.3	<10	26	64	94	1	11
R13060	B 37	.2	3.2	3.1	.03	9	.1	< .8	5	3	62	.5	1.2
R13036	C 6	.5	3.8	3.3	.04	13	.1	< .8	4	6	44	.7	3.6
R13086	C 8	.4	5.3	3.2	.04	12	.1	< 7	12	20	60	.5	3.1
R13039	C 10	.7	8.3	4.1	.08	16	.3	1	16	40	92	1.5	5.9
R13303	C 12	.4	4	3.2	.04	10	.1	<10	8	12	38	.4	3.2
R13042	C 14	.4	4.4	3	.04	10	.1	< .8	22	20	40	.4	3.3
R13309	C 16	.7	8	4.8	.03	18	.2	<10	13	13	60	.5	6
R13315	C 18	.7	8.5	7.5	.08	23	.2	<10	24	23	70	.5	7
R13046	C 20	.9	15	6.4	.12	37	.3	3.7	36	33	170	2.3	12
R13102	C 22	.6	8.2	4.3	.05	18	.2	< 5	10	17	74	.3	5.2
R13049	C 24	.5	4.6	3.6	.03	10	.1	< .8	5	4	54	1.2	4.2
R13106	C 26	.4	7.4	3.6	.09	12	.1	< 5	10	11	36	.3	2.9
R13219	C 37	.8	6	4.2		25	.3	<18	25		70	2.3	7.6
R13288	D 3	.3	3	2.4	.05	10	.1	<11	4	9	40	.4	.3
R13290	D 5	.4	4	4	.04	13	.2	<14	< 5	7	34	.3	3.3
R13292	D 7	.5	5	5	.04	14	.2	<12	23	19	40	.3	3.7
R13296	D 9	.8	10	5.8	.05	23	.3	<15	16	13	82	.6	8
R13088	D 11	.7	9.9	4.7	.05	21	.2	< 8	16	25	56	.5	6.1
R13090	D 13	.7	4.2	4.3	.06	21	.2	< 7	25	19	60	.3	5.3
R13385	D 15	.8	12	5.5	.05	22	.2	< 3	18	13	85	.8	7.5
R13097	D 17	.9	13.8	7.8	.06	31	.4	2	18	20	134	1	10.8
R13380	D 19	1	14	5.8	.05	33	.1	<10	10	6	62	.6	4.4
R13240	D 21	1.1	16	4.5	.17	39	.4	<16	39	110	120	3.3	11
R13237	D 23	1.2	15	5.2	.14	40	.4	<19	37	83	130	2.8	12
R13326	D 25	.6	7.5	5.7	.04	19	.1	<14	12	11	70	.3	5.5
R13231	D 27	.6	5	4.6	.03	16	.2	<14	13	8	60	.4	5.2
R13053	D 29	.3	5	2.6	.02	8	.1	< .8	4	9	65	.5	2.5
R13061	D 38	1.3	13	7.4	.61	34	.4	4.2	26	74	110	2.7	12
R13121	D 39	.4	3.7	3.3	.04	13	.1	< 8	3	2	42	.3	2.4
R13065	D 40	.8	2.5	4	.04	21	.2	14	15	2	42	.4	2.3
R13032	E 2	.5	4.4	10	.84	15	.2	2.4	5	3	63	.7	4.4
R13471	E 4	.6	4.6	2	.03	11	.1	<10	10	19	41	.6	3.3
R13475	E 6	.6	9.3	3.3	.04	14	.2	<10	12	8	61	.6	5.6
R13479	E 8	.6	8	5.7	.04	18	.2	<10	18	14	73	.8	7
R13483	E 10	.8	17	5.6	.12	33	.4	<10	39	36	128	1.3	12
R13392	E 12	1	15	5.5	.13	35	.3	<10	42	106	110	2.3	11
R13307	E 14	1.2	15	5.4	.16	33	.3	<13	37	92	114	2.4	11
R13310	E 16	1.5	22	6	.05	44	.3	< 6	30	23	120	.5	13
R13316	E 18	.3	4.7	3.2	.04	11	.1	< 7	9	24	40	.3	2
R13321	E 20	.8	12	5.3	.06	24	.2	<10	27	16	90	.5	8
R13323	E 22	1.2	18	4.7	.1	37	.3	< 9	42	100	105	1.9	11
R13376	E 26	.6	8	5.7	.07	20	.2	18	18	15	78	.4	6.5

Lab. no.	Geol. no.	Eu (ppm)	Ga (ppm)	Hf (ppm)	Hg (ppm)	La (ppm)	Lu (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Rb (ppm)	Sb (ppm)	Sc (ppm)
R13109	E 28	1	12.8	5.7	.10	31	.3	< 8	28	67	87	1.3	9.1
R13110	E 30	.4	4	3.2	.07	13	.2	< 8	3	15	53	.5	2.9
R13113	E 32	.6	9.1	5	.02	16	.2	< 8	5	10	63	.4	4.7
R13116	E 34	.3	2.8	2.2	.02	10	.2	< 8	1	5	41	.2	2.2
R13369	E 39	1.3	15	5.1	.5	33	.3	< 8	34	68	89	2.5	11
R13214	E 40	1.9	5	4	.07	76	.3	<13	97	30	42	1.7	2.7
R13126	E 41	1.2	14	10	.09	34	.5	< 7	25	9	126	.8	11.6
R13082	F 1	.3	2.4	4.4	.02	14	.1	< 8	3	7	18	.6	1.7
R13083	F 3	1	14.3	4.5	.04	29	.3	11	25	16	103	1.6	9.8
R13034	F 5	.6	5.2	7.6	.14	12	.2	< .8	13	17	79	.5	4.1
R13477	F 7	.8	11.5	5.5	.04	22	.3	8	26	8	100	.6	8.8
R13297	F 9	1.3	20	4.5	.16	40	.5	<13	43	102	140	2	13
R13485	F 11	1.3	19	5.3	.06	37	.5	9	43	30	137	1.7	13
R13390	F 13	1	16	4.6	.14	40	.3	6	41	33	136	.9	12
R13094	F 15	.8	13.3	5.3	.03	31	.4	< 8	36	24	116	.8	10.2
R13383	F 17	.6	10	5.2	.08	18	.2	<10	13	12	64	.5	5.1
R13100	F 19	1.1	16	6.5	.14	37	.4	3	39	112	125	2.8	11.1
R13241	F 21	.6	7	3.7	.02	17	.2	<13	11	12	60	.4	4
R13235	F 25	1.2	18	6.8	.03	42	.4	<24	23	10	110	.6	10
R13232	F 27	1.4	15	6.6	.04	44	.4	<17	27	14	110	.8	11
R13229	F 29	1.1	13	5.6	.06	36	.4	<14	31	38	120	1.5	11
R13227	F 31	1.1	13	5.8	.06	38	.4	<15	26	36	124	.7	11.7
R13334	F 35	.4	6	2.5	.03	9	.1	<10	7	3	50	.4	3
R13362	F 41	1.9	7.3	3.3	.05	71	.2	11	177	52	54	1.6	2.4
R13209	F 42	1.6	16	7	.25	40	.5	<18	43	91	100	3.1	12
R13355	F 43	1	6.9	5.1	.12	35	.2	< 8	53	23	74	.7	2.3
R13073	F 44	.3	3.4	2	.09	12	.1	3.4	3	4	22	.5	1.8
R13287	G 2	1.1	17	5	.04	33	.5	14	38	15	185	.9	15
R13472	G 4	.3	4.2	2.5	.04	8	.1	<10	8	20	50	.5	2.5
R13085	G 6	1	12.7	6.6	.04	27	.3	< 8	20	13	94	.5	8.7
R13037	G 8	.9	13	5.2	.15	26	.5	2.8	31	18	160	1.2	9.4
R13300	G 10	1.1	17	5.3	.2	36	.4	<10	44	133	100	2.4	10
R13041	G 12	1.2	13	5	.09	34	.7	3.8	36	53	220	1.3	13.2
R13388	G 14	.9	14	4.6	.11	34	.3	15	40	94	122	2.4	11.6
R13311	G 16	.6	10	3.4	.02	16	.1	<15	25	40	50	.4	4
R13317	G 18	.3	5.4	4.2	.03	12	.1	< 9	6	12	62	.4	3.1
R13243	G 20	.4	4	2.4	.02	12	.1	<20	6	9	40	.2	2
R13324	G 22	.7	10	3.3	.61	20	.1	< 9	38	128	60	.4	5
R13104	G 24	1.2	20	5.5	.19	38	.3	6	41	132	135	4	11.8
R13107	G 26	1.2	14.1	7.5	.04	32	.3	< 8	14	8	100	.5	8.1
R13328	G 28	1	14	6	.04	31	.3	< 8	26	18	100	.8	9
R13330	G 30	1	6	4	.12	33	.2	< 9	39	76	120	2.0	11
R13332	G 32	1.2	20	4	.14	35	.3	< 5	42	88	140	1.7	13
R13057	G 34	1	15	5.8	.09	32	.3	3.5	34	36	96	1.1	9.2
R13118	G 36	.4	4.9	4.7	.08	14	.2	< 9	7	7	72	.5	4.4
R13066	G 41	1.1	12	11	.16	28	< .1	2.9	30	9	78	.6	6.8
R13491	G 42	.8	5	5.2	.02	19	.3	< 8	68	16	100	.5	2.1
R13360	G 43	1.3	13.4	6.8	.11	34	.3	<10	198	36	107	.9	11.2
R13204	G 44	.6	3.6	6	.1	20	.2	<10	17	7	70	.6	1.4
R13508	G 45	.3	3.5	5	.03	12	.2	< 7	< 2	2	66	.5	1.8

Lab. no.	Geol. no.	Eu (ppm)	Ga (ppm)	Hf (ppm)	Hg (ppm)	La (ppm)	Lu (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Rb (ppm)	Sb (ppm)	Sc (ppm)
R13289	H 3	.5	5	4.2	.04	11	.1	<11	8	36	39	.5	3
R13473	H 5	.8	11	5.6	.14	25	.3	<20	28	87	102	1.5	10
R13293	H 7	1.1	14	7.2	.04	32	.4	<14	26	14	110	.6	10
R13087	H 9	1	16.1	4.9	.04	34	.4	< 8	24	11	100	.6	9.5
R13302	H 11	1	15	4.5	.16	32	.4	<11	39	90	104	1.9	10
R13092	H 13	.9	13	5.1	.04	38	.4	< 7	23	23	117	2.6	11.4
R13386	H 15	.9	14	4.1	.04	24	.2	15	23	23	75	.7	6.3
R13044	H 17	.6	8.4	6.4	.06	18	.2	< .8	11	7	100	.6	5
R13045	H 19	.9	11	6.3	.09	25	.7	2.1	24	5	160	1.4	8.7
R13047	H 21	.6	8	3.2	.03	15	.1	< .8	29	76	70	.6	2.2
R13238	H 23	.5	6	3	.04	18	.2	<25	12	8	60	.5	4
R13051	H 25	1.1	13	7.4	.23	35	.4	4.3	44	104	180	3.5	11.7
R13233	H 27	.9	10	5.2	.05	28	.3	<25	17	16	100	.6	7.3
R13375	H 29	1	16	4.7	.15	33	.2	<12	41	98	120	2.3	10.4
R13055	H 31	.6	7.6	5.9	.10	17	.2	< .8	41	61	90	.4	4.6
R13226	H 33	1	17	4.6	.17	36	.4	<20	40	88	120	3.6	13
R13224	H 35	1.4	19	5	.1	43	.5	<14	39	50	148	1.7	14
R13220	H 37	.6	6	4.4	.03	15	.2	<19	9	9	60	.4	4.5
R13122	H 39	.3	5.1	3.5	.02	10	.1	< 8	8	11	52	.3	2.4
R13071	H 43	1.3	7.8	8.3	.11	41	.4	6.5	62	14	99	1	8.1
R13353	H 45	.6	3.5	2.6	.03	26	.1	< 8	8	10	46	.4	1
R13077	H 46	.3	3.1	3.2	.01	11	.1	1.4	< 1	3	39	.7	1.1
R13084	I 4	.5	5.1	4.4	.08	17	.2	< 8	14	52	76	1.1	5.5
R13476	I 6	.7	9	5	.1	22	.3	<10	28	70	90	1.1	7.7
R13038	I 8	1	13	6.7	.21	33	.4	2.9	38	47	150	3.8	11
R13301	I 10	1	14	4.6	.23	32	.3	<12	58	132	100	1.9	10
R13304	I 12	1	16	3.2	.2	33	.2	17	39	93	84	1.5	8
R13308	I 14	1.2	17	4.5	.2	34	.3	<10	40	125	120	2.5	12
R13312	I 16	1	18	6	.06	38	.3		27	22	110	.5	9.4
R13319	I 18	.8	13	5.3	.04	30	.3	< 7	41	14	130	.6	12
R13322	I 20	1.2	17	4.4	.23	35	.3	<11	42	132	120	2.6	11
R13325	I 22	.8	12	3.6	.06	28	.2	<10	25	23	76	.4	6.6
R13050	I 24	.7	9	5.2	.12	22	.3	2	27	19	140	1.2	7
R13377	I 26	1.1	17	4.6	.17	33	.3	<10	52	72	180	2.4	11
R13052	I 28	.5	6.7	3.9	.09	18	.2	< .8	11	32	90	.7	3.8
R13111	I 30	1.5	23	5.2	.05	49	.5	< 8	44	<38	180	2.4	16.4
R13114	I 32	1.2	16	4.1	.28	38	.4	< 8	68	86	130	2.5	12.7
R13372	I 34	.7	11	4.3	.1	25	.2	8	28	56	92	.8	7
R13335	I 36	1.3	19	4.2	.18	35	.3	<10	40	89	150	1.9	13
R13062	I 38	.7	5.7	7.3	.05	18	.2	< .8	12	10	71	1.2	4.8
R13215	I 40	1.2	16	5	.02	38	.4	<16	13	12	160	1.1	13
R13361	I 43	.6	6.2	6		13	.1	<10	10	6	75	.4	3.4
R13205	I 44	.6	4.9	8	.02	17	.3	< 9	5	3	60	.6	2.2
R13075	I 45	.4	2.8	4.3	.01	10	.2	< .8	< 2	2	62	.8	1.5
R13033	J 3	.4	5	10	.14	11	.2	< .8	2	4	70	.5	2.5
R13291	J 5	.9	10	3.6	.23	23	.3	<18	26	110	93	1.2	8.9
R13478	J 7	.6	7	4.3	.08	16	.2	<10	16	52	60	.7	4.7
R13298	J 9	1	13	4.6	.19	30	.3	<11	32	110	90	2.3	9
R13486	J 11	.7	12	5.3	.05	26	.3	< 7	29	14	114	.5	10
R13306	J 13	1	16	5.2	.07	28	.2	<16	27	53	104	1.2	9

Lab. no.	Geol. no.	Eu (ppm)	Ga (ppm)	Hf (ppm)	Hg (ppm)	La (ppm)	Lu (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Rb (ppm)	Sb (ppm)	Sc (ppm)
R13387	J 15	.7	11	5.4	.03	25	.2	<10	24	12	96	.8	8.7
R13384	J 17	1.1	17	5.2	.12	36	.3	< 5	35	56	120	1.5	11.7
R13381	J 19	1	17	5	.1	34	.3	<10	37	53	108	1.5	10
R13242	J 21	1.2	17	4.8	.24	38	.4	16	38	104	130	2.3	12
R13378	J 23	1.1	17	5	.22	32	.3	<10	43	150	110	2.5	11
R13327	J 25	1	14	4.8	.05	29	.2	< 9	26	21	120	1.3	11
R13234	J 27	1.3	20	5	.2	45	.4	<20	37	133	130	3.5	12
R13230	J 29	1.1	12	4.3	.14	38	.3	<17	36	92	116	2.2	12
R13228	J 31	1.2	14	4.3	.08	42	.4	<20	44	50	130	2.4	12
R13487	J 33	.9	14	4	.14	33	.4	< 8	44	90	150	1.2	12.5
R13059	J 35	1.1	18	4.3	.18	36	.3	4.2	40	76	112	3	11.3
R13370	J 37	1	17	4	.21	33	.3	11	43	105	123	1.8	11
R13367	J 39	1.2	16	4.4	.09	36	.3	< 9	37	53	123	.8	12
R13067	J 41	.5	5	4.6	.13	12	.2	< .8	14	9	61	.2	1.2
R13506	J 44	.9	11	5.3	.21	28	.4	< 7	25	59	83	1.7	8.3
R13200	J 46	.3	3.2	3	.02	8	.1	< 7	< 2	2	38	.3	1.5
R13474	K 4	.5	4.2		.02	17	.4	<10	3	12	53	.5	4.8
R13035	K 6	.7	6.9	7.9	.13	15	.2	2.3	8	48	85	1.2	5.1
R13481	K 8	.6	10	4.7	.24	23	.3	<10	28	120	79	2	8.4
R13484	K 10	.8	11	4.4	.23	22	.4	<10	37	146	91	2.3	9.7
R13393	K 12	1.1	15	5	.09	34	.3	15	31	28	113	1	11
R13389	K 14	.7	10	4.5	.06	22	.2	13	18	34	77	.9	6.3
R13313	K 16	.9	13	5	.18	32	.3	<11	35	90	110	.7	10
R13318	K 18	.8	13	5	.18	29	.3	< 8	34	62	116	2.1	11
R13379	K 20	1.1	16	5.1	.31	32	.3	7	35	109	106	2.8	10.4
R13103	K 22	1	14.5	4.4	.29	31	.3	< 5	39	147	100	2.8	9
R13105	K 24	1.2	20	5.8	.30	35	.4	3	40	142	130	4.7	11.5
R13108	K 26	.4	7	3.8	.07	15	.2	< 8	3	5	63	.2	2.4
R13329	K 28	1	16	4.9	.2	33	.3	<12	40	133	130	2.8	12
R13331	K 30	1	15	4.2	.14	30	.2	< 8	40	56	120	1.7	11
R13333	K 32	1.3	19	4.2	.12	38	.3	< 9	42	48	140	.8	13
R13117	K 34	1.2	18	4.8	.12	42	.5	< 9	44	30	143	4	13
R13119	K 36	1.1	18	4.6	.25	35	.4	11	40	90	124	3.6	11.5
R13498	K 38	1.1	15	3.2	.2	28	.3	< 6	39	84	104	2	10
R13495	K 40	.8	4	4.5	.13	30	.4	< 6	36	34	142	.9	13
R13210	K 42	.5	4.5	3	.03	13	.2	<13	17	4	50	.4	1.2
R13128	K 43	.7	6.6	6.3	.04	19	.2	14	23	12	86	.4	4.6
R13294	L 7	.4	3	4.3	.07	9	.1	<14	4	20	40	.3	1.8
R13299	L 9	1	12	4.6	.28	28	.3	<12	26	153	80	2.1	9
R13089	L 11	1.3	16.5	4.9	.23	33	.4	< 7	34	105	104	4.4	10.3
R13391	L 13	.8	12	5	.24	29	.4	<10	38	135	97	2.2	9.4
R13095	L 15	.9	12.2	5	.15	29	.3	< 8	25	66	103	2.4	8.6
R13098	L 17	.6	8.9	4.2	.08	21	.2	< 5	13	26	79	1.4	6
R13101	L 19	.6	5.8	5.2	.06	15	.2	< 5	9	11	74	.5	4.3
R13048	L 21	.5	5.6	5.8	.04	11	.1	< .8	4	9	70	.7	2.6
R13236	L 25	.4	5	3.2	.05	13	.1	<17	8	13	54	.3	2
R13054	L 29	1	15	7	.25	30	.3	4.2	40	126	140	2.4	9.4
R13374	L 31	.8	13	4.8	.06	28	.2	<10	31	9	108	.7	9.3
R13056	L 33	1.1	17	6	.08	36	.3	4.4	45	22	157	2.7	8.8
R13225	L 35	.7	10	4.3	.04	28	.2	<10	12	9	70	.4	5.3

Lab. no.	Geol. no.	Eu (ppm)	Ga (ppm)	Hf (ppm)	Hg (ppm)	La (ppm)	Lu (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Rb (ppm)	Sb (ppm)	Sc (ppm)
R13221	L 37	1.2	20	4.3	.26	40	.4	<17	40	91	140	1.9	13
R13123	L 39	1.1	15	4.6	.24	35	.4	6	41	105	72	3.1	4.4
R13363	L 41	.6	9.6	6.8	.15	21	.3	13	35	67	117	.8	10
R13359	L 43	.6	8.7	5.5	.06	18	.2	< 9	9	6	74	.4	4
R13074	L 44	.6	7.8	6.7	.03	18	< .1	< .8	11	9	60	.6	4
R13507	L 45	.4	4.3	4.2	.05	11	.2	< 5	19	9	52	.3	2.1
R13482	M 8	.3	4		.05	11	.3	<10	1	9	44	.6	2.8
R13040	M 10	.7	7.8	5.6	.18	20	.3	3.9	23	80	90	1.9	5.7
R13305	M 12	1	13	5	.2	29	.2	< 8	31	120	96	2.1	10
R13043	M 14	.9	12	4.2	.35	26	.2	3.5	29	134	150	3.4	9.7
R13314	M 16	1	14	4.4	.28	30	.2	<11	36	128	100	2.3	9
R13320	M 18	.4	5	4.8	.05	14	.1	<12	8	11	65	.6	3
R13112	M 30	.3	1.4	2.4	.03	<11	.1	< 8	1	< 1	43	.3	.8
R13115	M 32	1.1	16	5.4	.25	34	.4	< 7	30	96	110	3.2	10.4
R13373	M 34	.8	13	4.4	.24	29	.2	<10	35	80	106	2.4	10
R13336	M 36	1.1	16	5.5	.21	33	.3	< 9	38	128	115	2.4	10
R13063	M 38	1.1	12	6.8	.25	28	.3	3.4	42	54	104	1.3	9.7
R13216	M 40	.5	6	18	.09	17	.4	<12	40	34	65	.8	5
R13069	M 42	1.2	18	6.8	.48	34	.3	4.2	43	86	106	1.5	10.3
R13505	M 44	1.2	16	6.2	.04	31	.4	< 5	33	30	118	.7	10
R13201	M 46	.5	4.6	6	.02	12	.2	< 9	17	3	62	.4	1.9
R13091	N 13	.3	4.4	5.6	.03	10	.1	5.4	3	8	34	.3	1.7
R13096	N 15	.3	1.4	2.2	.02	7	.1	< 5	3	2	30	.2	1.2
R13222	N 37	1	12	5.3	.1	27	.3	<10	23	46	95	1.8	8.5
R13124	N 39	.7	12.7	5.3	.04	23	.2	< 7	17	7	94	.6	7.1
R13494	N 41	1.1	12	5	.21	35	.4	< 5	39	52	110	1.8	10
R13129	N 43	.5	9.6	5.7	.14	18	.4	< 8	38	43	153	1.8	12.6
R13352	N 45	.9	10.4	6	.18	26	.2	< 6	27	20	93	1	8
R13347	N 47	.3	2.3	2.2	.08	10	.1	< 8	3	< 2	30	.2	.9
R13120	O 36	.3	3.9	2	.02	10	.1	10	< 2	1	70	.1	1.5
R13499	O 38	.2	3.2	5.2	.06	9	.2	< 9	4	12	45	.4	1.8
R13125	O 39	.2	.8	2	.04	8	.1	8	< 2	2	26		.5
R13496	O 40	.7	9	5.2	.05	19	.3	< 5	13	11	86	.4	6.5
R13211	O 42	1.3	19	6	.2	38	.5	<12	38	120	130	1.6	12
R13206	O 44	.7	7	5	.04	22	.3	<12	19	5	93	.4	6
R13078	O 46	1.2	19	7.5	.07	32	.4	2.4	28	55	110	1.3	10.3
R13079	O 48	.3	2.8	10	.01	9	.2	< .8	< 1	3	50	.7	1.3
R13488	P 38	.3	3.5	4.6	.03	9	.1	< 5	4	3	46	.2	1.6
R13364	P 41	.7	16	9	.04	28	.2	< 7	11	6	71	.3	4.4
R13358	P 43	.8	12.4	4	.12	25	.2	<10	22	8	97	.3	8.4
R13348	P 47	.5	2.9	6.8	.04	14	.2	< 9	2	3	50	.2	2.4
R13497	Q 38	.2	3	4.2	.04	8	.1	< 5	2	8	41	.2	1.5
R13368	Q 39	.4	3.2	3	.04	10	.1	< 8	7	10	41	.3	1.5
R13217	Q 40	.4	3	4	.04	15	.1	<15	8	5	46	.2	2
R13068	Q 41	.4	6.6	8.1	.05	10	.1	< .8	3	8	59	.1	1.9
R13492	Q 42	.6	4.6	5.2	.02	19	.2	< 8			106	.6	2.5
R13504	Q 44	.3	3.7	3.5	.04	9	.1	< 8	3	3	64	.3	1.6
R13196	Q 48	.4	4	8	.04	11	.2	<12	7	12	73	.3	2
R13365	R 41	1	12	4.2	.08	27	.2	< 8	23	14	95	.5	9
R13493	R 42	.5	9	5	.08	35	.2	< 5	14	24	68	.6	5

Lab. no.	Geol. no.	Eu (ppm)	Ga (ppm)	Hf (ppm)	Hg (ppm)	La (ppm)	Lu (ppm)	Mo (ppm)	Ni (ppm)	Pb (ppm)	Rb (ppm)	Sb (ppm)	Sc (ppm)
R13130	R 43	1.1	32	5.6	.08	34	.2	< 8	39	120	58	1.3	3.6
R13503	R 44	.2	1.8	1.4	.04	6	.1	< 8	3	4	26	.2	.9
R13076	R 45	1	11.3	8.5	.14	31	.3	2.3	28	103	92	1.5	8.4
R13489	S 38	.6	6.6	3.5	.03	15	.2	< 8	17	12	52	.3	3
R13366	S 41	.5	6.2	4	.04	12	.2	< 9	5	10	54	.5	3
R13212	S 42	.3	7	4	.03	10	.1	<15	3	4	30	.3	1.2
R13357	S 43	.4	4.4	4	.04	13	.1	< 8	7	8	51	.2	2.2
R13207	S 44	.4	4.4	6	.03	12	.2	<13	7	8	50	.2	2.1
R13197	S 48	.2	< 4	2	.02	10	.1	<11	< 2	< 2	28	.3	1.3
R13490	T 38	.2	4.2	2.8	.05	10	.1	< 8	5	2	39	.3	1.8
R13064	T 39	.3	5.4	2.7	.01	8	.1	< .8	< 2	3	25	1.2	.8
R13218	T 40	.4	8	5	.04	16	.2	<18	4	3	47	.2	3
R13127	T 41	.3	2	3.7	.02	10	.1	< 7	4	5	47	.3	1.3
R13070	T 42	.8	12	8.6	.03	20	.2	< .8	10	4	60	.2	4.9
R13500	T 43	.8	12	4.4	.1	28	.4	9	40	116	68	2.3	10
R13502	T 44	.3	3.5	3.7	.01	11	.1	<10	4	4	36	.2	1.6
R13351	T 45	.4	3.6	8.1	.17	11	.1	< 8	5	2	40	.2	1.7
R13346	T 48	.3	4.1	3.1	.04	8	.1	< 9	2	2	50	.3	1.1
R13081	T 50	.8	12.3	13	.11	19	.3	< .8	11	32	82	.9	4.8
R13213	U 42	.4	< 5	3	.04	9	.1	<12	7	6	38	.2	1.3
R13131	U 43	.3	3.5	2	.03	11	.1	< 8	23	8	32	.6	1.2
R13208	U 44	.7	6.9	8	.18	20	.2	<17	63	24	70	.5	4.1
R13350	U 45	.2	3.3	2.5	.06	8	.1	< 7	2	2	23	.2	.8
R13202	U 46	.4	4.3	3	.1	14	.1	< 7	7	12	38	.2	1.1
R13198	U 48	.3	3.7	8	.08	12	.2	< 9	4	9	60	.4	2.2
R13344	U 49	.2	2.2	2.3	.04	8	.1	< 8	< 5	< 2	23	.1	1.2
R13194	U 50	.3	2.6	10	.04	9	.2	<10	< 1	4	54	.3	1.3
R13072	V 43	.9	13	7	.11	29	.2	1.5	27	14	64	.6	6.1
R13501	V 44	.3	3.9	3.7	.08	12	.1	<10	21	8	38	.3	1.6
R13349	V 45	.3	5.7	3.3	.04	12	.2	<20	6	11	33	.2	1.1
R13345	V 48	.6	8	9	.04	13	.2	< 7	8	6	70	.2	2.5
R13195	V 49	.6	10	12	.11	15	.2	<10	8	25	83	.5	2.8
R13356	W 43	.3	5.7	3	.08	9	.1	< 7	1	< 2	45	.1	1.2
R13203	W 46	1	13	8	.12	27	.3	< 9	21	57	90	1.5	8
R13080	W 48	.77	12	10	.02	18	.2	< .8	18	33	85	1.4	4.6
R13199	X 48	.4	2.6	9	.09	11	.2	< 4	6	12	62	.4	1.7

Lab. no.	Geol. no.	Se (ppm)	Sm (ppm)	Sr (ppm)	Ta (ppm)	Tb (ppm)	Th (ppm)	U (ppm)	V (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)	Zr (ppm)
R13058	A 35	.6	2	73	.42	.2	.4	< 1.5	10	< 2	1.3	31	89
R13295	B 9	.6	1.7	115	.2	.2	2.5	< 2		< .5	.8	47	
R13093	B 15	.2	3.7	110	.42	.4	4.3	2.9	25	1.1	1.5	39	81
R13382	B 17	< .6	2.4	142	.28	.3	3	< 2		< 1	1	26	
R13099	B 19	.9	5	78	.7	.5	7.7	2.4	75	2.4	2.5	172	228
R13239	B 21	.6	2.1	110	.2	.2	3	< 4		< 2	.8	15	
R13223	B 35	1.4	4.1	94	.5	.5	5.2	5.2		1.2	2.1	94	
R13371	B 36	3	6.3	124	.85	.6	10.2	2.9		1	2.4	122	
R13060	B 37	.7	1	72	.14	.1	1.3	< 3	< 1	< 1.4	.6	6	26
R13036	C 6	.4	2.1	140	.23	.3	3	1.4	11	< .6	.8	39	40
R13086	C 8	.1	1.7	120	.25	.3	2.4	< 2	8	< 1.5	1.1	30	71
R13039	C 10	1.2	2.6	218	.42	.4	4.9	2.4	40	.8	1.7	68	124
R13303	C 12	< .5	2	120	.2	.2	3	1.6		< .6	.8	22	
R13042	C 14	1.1	1.5	172	.15	.2	2.2	1.7	2.5	1	6	35	34
R13309	C 16	< .3	1.7	130	.3	.4	4.2	1.7		< .8	1.5	29	
R13315	C 18	< .5	4.1	150	.5	.5	6.9	1.1		< 1	1.7	84	
R13046	C 20	1.1	5.7	194	1	.6	10.4	2.3	108	1.8	2	120	224
R13102	C 22	< .2	3.1	100	.37	.4	4.6	1.2	25	< .5	1.5	42	99
R13049	C 24	< 1	1.6	77	.24	.2	3.4	< 3	14	< 1	.9	20	36
R13106	C 26	< .5	1.8	80	.24	.2	2.2	1.1	22	2	.7	19	74
R13219	C 37	2	4.7	130	.4	.4	6.7	3.8		< 1.5	2	100	
R13288	D 3	< .4	1.8	111	.2	.2	1.6	< 1.7		< .5	.8	25	
R13290	D 5	< .3	1.8	90	.2	.2	3.5	1		.6	.8	14	
R13292	D 7	< .5	2.3	144	.3	.3	3.7	1.3		.7	1	38	
R13296	D 9	< .4	3	130	.5	.5	5.7	2.2		.7	1.7	49	
R13088	D 11	.2	3.1	74	.42	.4	4.8	< 1.5	45	< 2	1.5	71	125
R13090	D 13	< .4	3.3	77	.36	.4	4.7	< 2	37	< 2	1.4	42	114
R13385	D 15	< 1	3.7	140	.45	.5	6	1.7		.4	1.6	50	
R13097	D 17	< .1	4.7	130	.52	.9	8.7	2.6	78	2.6	2.6	47	229
R13380	D 19	< .5	5.6	130	.37	.3	4.5	3.6		1.7	1.2	26	130
R13240	D 21	2	5.7	170	.8	.7	8.7	2.8		1.5	2	270	
R13237	D 23	1.7	6	140	.8	.7	9	< 2.5		1.2	2.4	200	
R13326	D 25	< .5	3.1	150	.4	.4	4.6	< 2		1.3	1.4	29	
R13231	D 27	.5	2.1	115	.3	.3	3.6	< 1.9		< .7	.9	21	
R13053	D 29	1	1.2	67	.12	.2	2.5	< 3	8	< 1.7	.7	14	41
R13061	D 38	< 2	6	283	.52	1.1	10	2.5	77	1.4	2.8	100	190
R13121	D 39	< .4	1.8	<50	.12	.2	2	< 2		.8	1	16	
R13065	D 40	1.1	3.5	91	.28	.3	3.3	< 2	50	< 1.1	1.2	38	52
R13032	E 2	< 1	2.6	130	.5	.4	8.6	< 5	26	< .5	1.5	40	102
R13471	E 4	.7	2.1	114	.2	.3	2.5	< 1		< 1	.8	54	
R13475	E 6	< 1	2.6	138	.4	.3	4.2	< 2		< 1	1.4	38	
R13479	E 8	< .8	3.1	159	.5	.4	5.7	2.2		.7	1.6	53	
R13483	E 10	1	5	180	.8	.7	9.8	2.2		.9	2.5	108	
R13392	E 12	1.8	6.2	174	.65	.7	10.2	3.2		1.6	2.4	236	
R13307	E 14	1.1	5	180	.8	.7	9	3.5		1.1	2.7	193	
R13310	E 16	< .3	6.5	210	.9	1	12	2.7		< .6	3.4	76	
R13316	E 18	< .4	1.7	140	.2	.2	2.7	< .6		< .9	.7	27	
R13321	E 20	< .4	4	180	.5	.5	7.6	< 1.5		.8	1.9	69	
R13323	E 22	1.4	6	160	.6	.6	9.5	< 2		1	2.5	240	
R13376	E 26	.6	3.4	152	.5	.2	6.3	< 2		< 1	1.6	41	

Lab. no.	Geol. no.	Se (ppm)	Sm (ppm)	Sr (ppm)	Ta (ppm)	Tb (ppm)	Th (ppm)	U (ppm)	V (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)	Zr (ppm)
R13109	E 28	1	5.4	130	.7	.7	6.7	1.2	67	< 2	2.6	127	156
R13110	E 30	< .5	2	58	.2	.3	2.2		19	< 2	1.2	15	64
R13113	E 32	< .3	2.7	<70	.22	.3	3.1	1.4	29	< 2	1.3	17	95
R13116	E 34	< .4	1.4	39	.16	.1	1.6	4.1	11	< 2	.9	10	41
R13369	E 39	2	5.9	176	.65	.7	8.5	1.8		1.2	2.4	160	
R13214	E 40	1.5	10.6	160	< .1	1	3.2	1.8		1.2	2	135	
R13126	E 41	.5	5.5	103	.95	.8	9.6	2.1		1	3.5	63	
R13082	F 1	< .8	1.5	100	.21	.2	2.6	< 2	5	< 2	.7	43	60
R13083	F 3	.6	4.7	260	.67	.5	7.4	2.8	97	1.4	2.5	59	171
R13034	F 5	< 1	1.7	220	.32	.3	4.6	1.5	13	1.4	1.4	43	93
R13477	F 7	< .8	3.9	147	.6	.6	7.1	< 2		.5	2	57	
R13297	F 9	1.5	5.4	155	.9	.7	10	1.8		1.4	2.7	226	
R13485	F 11	1.7	5.9	156	.8	.7	10	2		1	2.6	106	
R13390	F 13	< 1	6.2	134	.75	.8	10.4	4		< 1	2.5	109	
R13094	F 15	.4	4.8	76	.6	.5	7.6	1.6	92	1.6	2.5	75	149
R13383	F 17	< .7	3.2	154	.4	.36	4.8	1		.7	1.4	30	
R13100	F 19	2	5.8	110	.68	.7	9.9	2.7	89	.9	2.7	225	281
R13241	F 21	.2	2.4	100	.3	.3	3.5	< 2		< 1.2	.9	23	
R13235	F 25	< .3	6.4	180	.7	.7	8	< 3		1.8	2.9	49	
R13232	F 27	< .3	7.1	190	.7	.8	9	< 2.5		< 1	2.5	57	
R13229	F 29	1.3	5.8	170	.7	.7	9.2	< 2.1		< 1	2	96	
R13227	F 31	.6	5.7	124	.6	.6	9	< 2.2		< 1.2	2	98	
R13334	F 35	< .5	1.6	150	.2	.2	2	1.7		< 2	1.7	12	
R13362	F 41	1.3	10.6	240	.23	1	3.2	< 1		2.1	2.3	193	94
R13209	F 42	3.3	6.8	146	.75	.9	9.4	2.8		1.9	3.2	200	
R13355	F 43	.8	5.4	140	.59	.6	3.6	< 1		.8	1.7	56	
R13073	F 44	< 1	1.8	<30	.13	.1	1.6	2.4	31	.6	.6	40	36
R13287	G 2	< .5	5.6	145	.7	.7	10	4.6		.8	2.3	52	
R13472	G 4	< .6	1.5	110	.2	.2	2.2	< 1		1.2	.8	32	
R13085	G 6	< .2	4.6	100	.58	.5	7	< 2	57	< 2	2.4	51	124
R13037	G 8	1.1	4	190	.54	.6	7	1.3	100	1.3	1.7	72	228
R13300	G 10	1.5	6	246	.9	.7	7.7	2.3		1.1	2.3	290	
R13041	G 12	2.5	5.7	238	.72	.8	10	3.0	104	.7	3.2	140	242
R13388	G 14	< 1	5.6	148	.75	.7	9.8	< 1		1	2.3	218	140
R13311	G 16	< .5	2.5	140	.3	.4	3.3	< 2		< .8	1	40	
R13317	G 18	< .4	2	130	.4	.2	3.4	< .8		.7	1	23	
R13243	G 20	2	1.6	93	.1	.1	2.1	< 3		< 1.8	.7	16	
R13324	G 22	< .5	3.3	110	.3	.3	4.8	2.2		.8	1.3	288	
R13104	G 24	2.6	5.5	100	.66	.6	10	3.2	77	1.4	2.8	272	220
R13107	G 26	< .5	4.7	<70	.63	.6	6.8	2.6	61	< 2	2.6	33	181
R13328	G 28	< .6	5.1	180	.6	.7	8.5	< 2		.7	2.4	61	
R13330	G 30	1	5.8	170	.7	.6	8.6	< 1.3		1.3	2.3	196	
R13332	G 32	1.1	5.6	190	.6	.7	9.6	1		.9	1	205	
R13057	G 34	1.3	4.8	88	.62	1.1	8.2	4.8	110	1.3	2.1	92	245
R13118	G 36	3	2.1	53	.3	.3	3.3	1	21	< 2	1.4	20	71
R13066	G 41	< 2	5.1	166	.6	.7	6.9	< 2	47	< 1.6	2.2	68	218
R13491	G 42	< .5	2.8	170	.2	.4	3.1	< .7		.7	1.5	42	
R13360	G 43	1.2	6.3	180	.66	.8	9.7	< 1.6		.7	2.8	108	202
R13204	G 44	< .6	2.8	48	.23	.4	3	< 1.1		< .8	1.6	31	
R13508	G 45	< .6	1.8	86	.2	.5	3.3	< 1.5		.9	1.4	7	

Lab. no.	Geol. no.	Se (ppm)	Sm (ppm)	Sr (ppm)	Ta (ppm)	Tb (ppm)	Th (ppm)	U (ppm)	V (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)	Zr (ppm)
R13289	H 3	< .5	2	107	.2	.2	2.3	1.3		< .5	1	52	
R13473	H 5	1	1.6	140	.7	.6	8.2	1.7		1	2.1	188	
R13293	H 7	1	4.7	140	.7	.6	9.6	< 2		< 1	2.3	64	
R13087	H 9	< .2	4.7	130	.72	.5	8.1	< 1.5	92	< 2	2.2	58	190
R13302	H 11	1.1	5.5	122	.7	.6	9.4	1.6		1.3	2.2	200	
R13092	H 13	1	6	176	.83	.7	9.3	< 2	78	1.2	2.8	56	190
R13386	H 15	< 1	4.1	65	.45	.5	5.6	3		< 1	1.4	56	
R13044	H 17	< .5	2.7	<60	.42	.4	4.9	1.2	23	< .7	1.3	44	260
R13045	H 19	< 2	4.1	307	.66	.6	7.8	2.3	57	.6	1.8	67	167
R13047	H 21	.7	2.4	166	.2	.2	3	1.2	5	.8	.7	64	52
R13238	H 23	.7	2.8	80	.3	.3	3.4	< 3		< 1.8	.8	29	
R13051	H 25	1.2	6.8	95	1.4	.7	13.6	3.2	129	< 3.3	2.9	220	276
R13233	H 27	< .3	4.6	120	.4	.5	6	< 3.7		1.6	1.5	39	
R13375	H 29	1.6	5.8	160	.72	.2	10	2.2		1.1	2.2	264	
R13055	H 31	< 1	2.7	50	.42	.4	4.9	3.3	11	< 1.8	1.8	168	92
R13226	H 33	1.5	6.4	150	.8	.8	10	4.3		1.2	3.1	230	
R13224	H 35	.3	6.7	116	.8	.9	11	2.6		1.5	3.2	135	
R13220	H 37	< .3	2.8	110	.3	.3	3.8	2.9		< .8	1.6	203	
R13122	H 39	< .3	1.5	56	.16	.2	1.9	< 2	11	< 2	.9	17	49
R13071	H 43	< 2	6	260	.72	1.0	8.2	3	59	< 1.5	2.6	66	186
R13353	H 45	< 1	4.6	80	.42	.4	2.2	1.6		.8	.9	49	67
R13077	H 46	< 1	1.5	<50	.23	.2	2.1	< 2	5	1.5	.7	15	43
R13084	I 4	.2	2.5	180	.43	.3	4.1	< 2	33	< 2	1.6	109	128
R13476	I 6	1	3.9	140	.7	.5	6.5	1.1		.6	2	148	
R13038	I 8	2	5.3	217	.94	.6	9.8	1.3	104	1.5	2.4	208	219
R13301	I 10	1.3	5.4	172	.7	.6	9.4	1.5		1.3	2.2	290	
R13304	I 12	.7	5.4	130	.5	.5	6.2	2.5		1.2	1.7	215	
R13308	I 14	1.8	5.4	165	.8	.7	9	3		.9	2.4	263	
R13312	I 16	< .5	6.5	180	.7	.7	1.1	< 1		.7	2.5	62	
R13319	I 18	< 1	5	170	.7	.7	9.2	.9		1.8	2.4	91	
R13322	I 20	1.3	6	150	.7	.7	9.6	< 2		< 1	2.3	286	
R13325	I 22	< .5	4.5	110	.4	.4	5.6	2.7		1	1.6	80	
R13050	I 24	< 1.5	3.5	93	.52	.4	7	< 3	51	< 1	2	65	193
R13377	I 26	1.6	5.5	140	.87	.2	9.4	1	64	1.1	2.2	290	140
R13052	I 28	< 1	2.8	<80	.36	.2	4.4	4.1	18	< 1.4	1.2	70	114
R13111	I 30	< .5	7.2	80	.82	1.2	11.6	2.1	88	1.9	3.8	<20	180
R13114	I 32	2	6.5	155	.88	.8	9.2	2.1	56	1.4	3.2	340	120
R13372	I 34	.6	4.1	110	.45	.5	7.7	2.8	68	.9	1.5	133	140
R13335	I 36	< 1	5.7	240	.7	.7	9.7	2.1		1.3	2.1	214	
R13062	I 38	< 1	2.7	267	.34	.3	3.8	< 2.2	25	< 1.2	1.2	50	121
R13215	I 40	1.6	6.3	100	.8	1.4	10.4	5		1.6	2.8	17	
R13361	I 43	.7	2.5	148	.32	.3	3.5	2.2		< 1	1.3	20	151
R13205	I 44	< .3	2.6	55	.36	.6	3.2	< 1.4		< .9	1.8	22	
R13075	I 45	< 1	1.3	47	.31	.3	3.1	< 1.9	4	< .7	1.3	6	60
R13033	J 3	< 1	1.5	214	.33	.2	3	4.3	5	< .7	1.1	20	88
R13291	J 5	1.2	3.7	140	.6	.5	8	1.7		1.2	1.9	320	
R13478	J 7	< 1	2.8	111	.4	.4	4.5	1.4		.5	1.3	113	
R13298	J 9	1.3	5.3	190	.8	.7	7.3	2.8		.7	2.3	240	
R13486	J 11	< 1	4.4	206	.7	.7	7.7	1.9		.9	2.5	67	
R13305	J 13	.8	4	160	.5	.6	7.5	2.5		< 1	2.1	131	

Lab. no.	Geol. no.	Se (ppm)	Sm (ppm)	Sr (ppm)	Ta (ppm)	Tb (ppm)	Th (ppm)	U (ppm)	V (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)	Zr (ppm)
R13387	J 15	< 1	4.2	150	.55	.5	7.6	< 1		< .7	2	54	
R13384	J 17	2.3	6	164	.7	.8	10	3.4		1.2	2.4	137	
R13381	J 19	< .7	5.6	116	.82	.6	9.2	1.1		2	2.3	134	150
R13242	J 21	1.7	5.4	120	.8	.7	9.3	4		1.3	2.1	235	
R13378	J 23	1.2	5.5	180	1	.2	9.6	1.3		2	2.3	342	
R13327	J 25	< .1	4.9	180	.7	.7	8.7	1.2		.6	2.2	70	
R13234	J 27	2	7.2	160	.9	.8	9	3.5		1.3	2.1	235	
R13230	J 29	1.8	5.7	113	.7	.6	9	< 2.5		< 1	2	198	
R13228	J 31	1.5	6.3	176	.7	.6	9.6	< 3.2		1.7	2.1	143	
R13487	J 33	1	5.4	224	.8	.7	8.9	2		1.1	2.4	217	
R13059	J 35	1.1	5.4	107	.84	.5	10	3.9	115	1.5	2.3	188	223
R13370	J 37	1.6	5.6	180	.84	.7	9.4	3		1	2.1	241	
R13367	J 39	2	6.2	160	.66	.7	8.7	2.9		.8	2.3	143	
R13067	J 41	.7	2	75	.16	.5	2.9	< 1.6	< 1	< 2.6	.9	20	52
R13506	J 44	3	4.8	166	.5	1	6.7	1.7		< 2	2.2	138	
R13200	J 46	< .5	1.3	50	.16	.2	2.3	< 1		< 1	.7	13	
R13474	K 4	< .7	3.1	117	.8	.4	6.6	< 1		< 1	2.5	40	
R13035	K 6	.5	2.6	250	.54	.4	5	9.2	21	1.1	1.4	107	142
R13481	K 8	1.4	4.3	180	.8	.6	6.8	3.4		1.5	2.1	285	
R13484	K 10	< 1	3.8	160	1	.6	8	2.6		1.2	2.3	318	
R13393	K 12	< 1	5.6	178	.67	.7	10	2.7		1.2	2.2	86	
R13389	K 14	.5	3.5	124	.47	.5	6	1.8		.8	1.5	79	
R13313	K 16	< .5	5.3	68	.7	.6	8.8	2.5		1.8	2.1	200	
R13318	K 18	1.5	5	170	.8	.6	9.4	1		1.1	2.3	148	
R13379	K 20	1.6	5.4	174	1.1	.2	9.3	2.1		1.5	2.3	247	
R13103	K 22	1	5	110	1.2	.6	8	2.8	93	1.5	2.5	350	232
R13105	K 24	1.1	6	<70	.88	1	9.5	2.5	86	2.3	2.9	318	235
R13108	K 26	< .4	2.1	32	.2	.3	2.8	1.1	10	< 2	1	16	79
R13329	K 28	< .5	5.9	80	.5	.4	4.8	4.5		.9	1.4	300	
R13331	K 30	1.2	5.2	187	.6	.6	8.4	1.1		1.4	1.1	152	
R13333	K 32	< .5	6.3	170	.6	.7	9.6	1.3		1.1	1.3	117	
R13117	K 34	2	6.5	162	.9	.8	9.4	2.9	77	1	3.2	103	133
R13119	K 36	1.5	5.2	113	.87	.6	9.1	4.7	84	1.2	2.6	224	175
R13498	K 38	1.3	5	136	.6	1	7	2		1.1	2	206	
R13495	K 40	.9	4.9	133	.8	.7	9.1	1.3		.7	2.4	113	
R13210	K 42	.6	2	67	.13	.3	2.1	< 2		.7	.9	10	
R13128	K 43	< .5	3	141	.27	.3	3.8	1		< 2	1.5	34	
R13294	L 7	< .3	1.4	94	.1	.2	2.3	< 2.5		< 1	.7	48	
R13299	L 9	1.1	4.7	180	.9	.5	6.7	2		.7	2.1	153	
R13089	L 11	1	4.8	110	1.1	.6	8.5	2.6	104	1.4	2.9	225	238
R13391	L 13	1.1	5	144	.72	.6	8.5	< 2		< 1	2.1	280	144
R13095	L 15	1	4.8	100	.8	.6	7.8	2	86	1.2	2.4	147	212
R13098	L 17	.7	3.3	72	.55	.4	5.8	2.7	44	2.7	1.9	67	121
R13101	L 19	< .5	2.6	87	.34	.4	4.6	1	17	< .5	1	35	110
R13048	L 21	< .5	2.1	111	.29	.2	3	< 3	9	< .8	1	22	72
R13236	L 25	.7	1.9	90	.2	.2	2.2	< 3		< 1.6	.7	24	
R13054	L 29	3.1	4.9	80	1.2	.6	11.2	< 3.7	110	2.5	2.6	282	272
R13374	L 31	< .5	5	70	.7	.2	8.8	1.4		< 1.5	1.9	65	
R13056	L 33	3	6.9	70	1	.5	9.8	< 3.6	130	< 2	2.5	172	253
R13225	L 35	.4	4	70	.4	.4	5.1	< 3		< 1.4	1.8	29	

Lab. no.	Geol. no.	Se (ppm)	Sm (ppm)	Sr (ppm)	Ta (ppm)	Tb (ppm)	Th (ppm)	U (ppm)	V (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)	Zr (ppm)
R13221	L 37	1.4	5.8	110	.7	.7	9.2	5.8		1.7	2	205	
R13123	L 39	1.3	2.1	<70	.9	.3	8.4	2	73	1.4	2.4	266	158
R13363	L 41	1.9	3.4	175	.65	.6	8.6	3.1		.7	2.4	157	
R13359	L 43	< .8	2.5	140	.3	.3	4.7	< 1.4		< 1	1.3	22	
R13074	L 44	< 1	2.5	200	.35	.4	4.4	< 1.8	24	< .8	1.2	43	108
R13507	L 45	< .5	1.9	113	.1	.3	2.2	1.8		< 2	.9	18	
R13482	M 8	< .4	2.5	120	.3	.3	3.6	1.2		< 1	1.4	20	
R13040	M 10	1.9	3.6	237	.7	.4	5.1	2.6	57	< .8	2	201	156
R13305	M 12	1	4.5	175	.9	.6	7.6	3		1.1	2.2	248	
R13043	M 14	3.2	3.9	<60	1.1	.7	7.4	4.0	89	1.8	1.7	262	193
R13314	M 16	< .5	4.4	170	1	.6	7.8	3.3		1.5	2.2	307	
R13320	M 18	< .4	2.4	130	.3	.3	3.2	< 1		< 1.4	1	28	
R13112	M 30	< .3	1.4	81	.1	.2	1.6	< 1	< 9	< 2	.6	6	48
R13115	M 32	1.2	5.1	<70	.81	.7	7.5	3.4	96	1	2.7	200	169
R13373	M 34	1.4	5.2	147	.9	.5	9.1	2.7		1.2	2.1	200	
R13336	M 36	< 1	5.1	185	1	.6	8.4	3.5		1.2	3.5	288	
R13063	M 38	3.3	5.2	49	.91	.6	9	< 1.5	116	< .7	2.1	241	233
R13216	M 40	.8	2.8	72	.66	.5	5.4	1.7		< 1.3	2.6	110	
R13069	M 42	3	6.5	138	.82	.6	9.4	2.4	120	1.2	2.3	214	233
R13505	M 44	1.2	5	177	.7	1.4	8	2.5		.6	2.3	98	
R13201	M 46	.4	1.8	90	.2	.2	2.6	< 1.5		< 1	1.3	16	
R13091	N 13	.2	1.3	66	.48	.2	2.1	.6	3	< 2	.9	22	43
R13096	N 15	< .5	1.1	63	.09	.1	1.7	< 2	< 9	< 2	.6	14	37
R13222	N 37	1	4.6	114	.7	.7	6.6	2.5		.7	2.2	118	
R13124	N 39	< .5	3.4	<70	.48	.4	6.2	2		.8	2	34	
R13494	N 41	1.8	5.7	194	.6	.6	8.2	2		1	2.3	136	
R13129	N 43	1.4	2.7	126	.85	.8	10.2	2.3		< 2	2.9	128	
R13352	N 45	2	4.6	187	.53	.5	7.4	1.6		.8	2.3	77	
R13347	N 47	< .4	1.6	76	.11	< .1	2.1	< 3		< 1	.6	8	
R13120	O 36	< .2	1.3	73	.13	.2	2	< 2	< 9	< 2	.7	4	31
R13499	O 38	< .6	1.5	96	1.6	.4	2.1	< 2		< 1	.8	25	
R13125	O 39	< .5	1	30	.06	.2	3.4	3		< 1	.6	5	
R13496	O 40	< .5	3.2	117	.4	.7	5.2	< 3		.6	1.5	40	
R13211	O 42	1.1	5.7	160	.8	.8	9.4	3.5		1.5	3.2	260	
R13206	O 44	< 1	3.4	70	.4	.4	5.7	< 1.9		< 1.2	1.6	30	
R13078	O 46	1	5	240	.82	.6	8.4	< 2	91	< 2.2	2.3	69	241
R13079	O 48	< 1	1.4	81	.31	.2	2.3	2.1	1	< .9	1	7	62
R13488	P 38	< .5	1.6	86	.1	.2	2.2	< .5		< 1	1	11	
R13364	P 41	< 1	4.8	145	.92	.5	4.6	1.6		.8	1.6	33	
R13358	P 43	< .5	4.3	180	.53	.5	7	1.3		< 1	1.7	57	
R13348	P 47	.3	2.2	130	.24	.3	3.2	< 1		.7	1.1	10	
R13497	Q 38	< .5	1.3	87	.1	.4	1.8	< 2		< .5	.7	20	
R13368	Q 39	< .5	1.7	90	.13	.2	2.1	< 2		< 1	.7	19	
R13217	Q 40	1	2.4	<30	.22	.2	3	< 2		< 1.5	.9	20	
R13068	Q 41	< 2	1.6	135	.18	.2	2	< 1.8	7	< .9	.9	25	73
R13492	Q 42	< .5	3.6	170	.2	.4	3.1	< .7		< 1	1.3		
R13504	Q 44	< .4	1.4	116	.1	.3	1.9	< 1		< 2	.7	14	
R13196	Q 48	< .3	2.2	100	.26	.3	3.5	< 2		< .8	1.3	18	
R13365	R 41	.6	4.6	160	.54	.5	6.8	2.7		.8	1.7	51	
R13493	R 42	.8	3.2	130	.3	.4	4.1	< 1		< 1	1.4	60	

Lab. no.	Geol. no.	Se (ppm)	Sm (ppm)	Sr (ppm)	Ta (ppm)	Tb (ppm)	Th (ppm)	U (ppm)	V (ppm)	W (ppm)	Yb (ppm)	Zn (ppm)	Zr (ppm)
R13130	R 43	.6	5.3	71	.28	.7	3.8	2		< 2	1.3	208	
R13503	R 44	< .5	1	61	.1	.2	1.3	1		< 2	.5	12	
R13076	R 45	1	4.4	270	.72	.6	8.3	< 2.5	80	< 2	2.0	150	249
R13489	S 38	< .6	2.3	106	.3	.3	3	1		1	1	37	
R13366	S 41	1	2	150	.2	.2	2.6	1		.7	1	23	
R13212	S 42	.2	1.3	50	.16	.2	1.9	3		< 1.6	.7	11	
R13357	S 43	.5	1.9	114	.2	.3	2.8	.7		< 1	.9	22	
R13207	S 44	< .3	1.7	54	.22	.2	2.8	< 2		< 1.2	1	16	
R13197	S 48	< .3	1.2	42	.16	.2	1.8	< 3		< 2	.8	5	
R13490	T 38	< .5	1.6	93	.2	.2	2	< .5		< 1	.7	15	
R13064	T 39	1.3	1.2	87	.09	.1	1.5	< 1.5	< 2	< .8	.5	7	15
R13218	T 40	.9	2.3	50	.3	.2	3.7	< 3		< 1.7	1.1	16	
R13127	T 41	< .5	1.3	62	.09	.2	1.8	1		< 2	.6	12	
R13070	T 42	< 1	3.4	106	.36	.4	5.2	< 2	22	< 1.4	1.4	37	139
R13500	T 43	2	4.4	178	.1	1	8.4	< 2		.6	2	211	
R13502	T 44	< .6	1.5	90	.1	.3	1.9	< 3		< 1	.7	10	
R13351	T 45	< .3	1.7	100	.19	.2	2.6	.8		< .8	.9	12	
R13346	T 48	< .5	1.2	140	.1	.1	1.6	< 3		< 1	.5	12	71
R13081	T 50	< 1	3.4	290	.63	.4	4.8	3	27	2.1	1.7	77	269
R13213	U 42	< .4	1.3	70	.11	.2	1.6	1.4		< 1.3	.8	19	
R13131	U 43	< .5	1.5	59	.12	.4	1.6	< 2		< 2	.6	38	
R13208	U 44	2	2.7	140	.33	.5	4.3	2.6		< 1.6	1.7	76	
R13350	U 45	< .5	1.1	46	.12	.1	1.2	1.1		< .7	.4	7	
R13202	U 46	< .3	1.8	<30	.1	.2	1.8	< 1		< .8	.8	25	
R13198	U 48	1	1.8	95	.27	.3	3.4	< 3		< 1	1.1	17	
R13344	U 49	< .4	1.2	90	.14	.1	1.4	< 2		< .8	.6	5	
R13194	U 50	< .3	1.5	60	.1	.2	2.6	< 1.2		< .7	1.1	7	
R13072	V 43	1	4.4	263	.54	.4	6.1	4.6	60	< 1.8	1.5	55	230
R13501	V 44	< .5	1.8	110	.1	.3	2.1	< 2		.4	.7	25	
R13349	V 45	< .5	1.9	80	.07	.2	1.8	< 2		< 1	.8	24	
R13345	V 48	< .5	2.4	153	.25	.3	3.4	1.1		< .4	1.2	14	
R13195	V 49	.4	2.3	124	.3	.3	3.8	< 1.2		< 1.5	1.5	31	
R13356	W 43	< .5	1.3	100	.13	.2	1.8	< 1		.7	.6	7	67
R13203	W 46	1	3.9	100	.56	.5	.7	< 1.5		< 1	2.2	112	
R13080	W 48	.8	3	340	.5	.4	5.4	< 2.1	32	< 1.8	1.4	81	133
R13199	X 48	.5	1.8	150	.23	.2	3.1	< .7		< .5	1	18	

Lab. no.	Geol. no.	pH	Eh (volts)	Sand (%)	Silt (%)	Clay (%)	Mean (φ)	Std. dev. (φ)	Skew	Kurt.	CO_2 (%)	Total
R13058	A 35	7.30	.09	75.00	17.10	7.91	3.54	1.31	0.48	3.52	2.00	93.58 %
R13295	B 9	8.10	.43	84.80	11.36	3.84	2.53	1.49	0.58	3.76	4.10	93.51 %
R13093	B 15	7.50	.39	99.98	0.02	0.00	1.47	2.05	0.10	-1.38	3.44	83.59 %
R13382	B 17	7.20	.42	67.68	24.23	8.09	3.17	1.73	0.44	0.93	3.86	90.60 %
R13099	B 19	7.50	.00	7.84	45.44	46.72	7.25	2.05	-0.05	-1.06	3.83	84.08 %
R13239	B 21	4.50	.39	75.82	19.34	4.84	2.97	1.54	0.64	1.83	3.30	90.45 %
R13223	B 35	7.20	.12	20.81	49.63	29.56	6.23	2.53	0.01	-0.64	3.19	85.31 %
R13371	B 36	7.20	.06	1.71	44.33	53.95	7.51	1.91	0.01	-1.28	2.96	84.96 %
R13060	B 37	7.40	.13	97.98	0.88	1.14	2.24	0.78	1.04	15.15	0.14	100.0 %
R13036	C 6	7.90	.40	99.99	0.01	0.00	0.02	1.91	-0.32	-0.98	3.71	88.41 %
R13086	C 8	7.80	.42	86.22	9.60	4.17	2.65	1.34	0.93	4.69	0.81	92.99 %
R13039	C 10	7.90	.32	57.26	23.23	19.51	4.05	2.58	0.41	-0.37	3.68	87.64 %
R13303	C 12	7.40	.37	82.12	13.15	4.73	2.61	1.53	0.73	2.65	3.89	93.65 %
R13042	C 14	7.50	.45	87.92	8.28	3.80	2.33	1.41	0.98	5.30	3.03	91.21 %
R13309	C 16	7.50	.40	72.12	15.38	12.50	3.06	1.72	0.67	1.86	3.15	92.20 %
R13315	C 18	8.00	.44	42.82	25.03	32.16	5.35	3.09	0.14	-1.25	2.12	90.11 %
R13046	C 20	7.40	.01	22.84	25.60	51.57	7.11	2.45	-0.12	-1.40	2.95	84.49 %
R13102	C 22	7.70	.37	67.02	16.38	16.60	3.71	2.33	0.70	0.82	2.99	91.43 %
R13049	C 24	7.90	.36	83.72	12.70	3.58	1.56	2.23	0.52	1.30	3.78	88.72 %
R13106	C 26	7.60	.32	75.65	19.76	4.59	3.11	1.49	0.58	1.60	4.02	88.34 %
R13219	C 37	7.10	.10	17.88	40.22	41.90	6.61	1.95	-0.11	-1.14	2.10	81.30 %
R13288	D 3	8.10	.17	96.88	1.89	1.23	2.56	0.81	1.22	17.32	3.22	91.70 %
R13290	D 5	8.00	.14	98.54	0.91	0.54	2.27	0.73	1.16	18.69	3.40	94.60 %
R13292	D 7	7.50	.38	80.05	12.97	6.97	2.74	1.81	0.09	3.17	3.13	92.95 %
R13296	D 9	7.80	.23	44.62	25.38	28.00	4.99	2.98	0.23	-0.88	3.12	89.82 %
R13088	D 11	7.70	.36	54.17	21.14	24.69	4.34	2.67	0.38	-0.67	3.50	86.82 %
R13090	D 13	7.70	.35	58.44	18.73	22.83	4.09	2.57	0.49	-0.20	3.28	86.11 %
R13385	D 15	7.50	.41	51.96	17.69	30.34	4.93	3.15	0.25	-1.13	2.47	92.57 %
R13097	D 17	8.10	.39	11.23	37.15	51.62	7.19	2.33	-0.08	-1.41	3.61	85.13 %
R13380	D 19	8.00	.41	68.19	14.21	17.61	3.16	2.88	0.38	0.27	3.03	97.66 %
R13240	D 21	7.70	.02	0.68	35.57	63.75	8.30	1.82	-0.15	-0.62	3.56	81.83 %
R13237	D 23	7.60	.04	2.52	34.08	63.40	8.36	1.88	-0.22	-0.32	3.71	81.13 %
R13326	D 25	7.60	.30	67.60	16.60	15.80	3.76	2.30	0.67	0.78	2.02	94.65 %
R13231	D 27	7.60	.29	47.72	40.71	11.57	4.27	2.09	0.43	0.32	4.13	83.54 %
R13053	D 29	7.60	.28	95.59	2.53	1.88	2.66	1.05	0.30	4.07	3.50	99.98 %
R13061	D 38	7.40	.04	6.25	43.32	50.43	7.36	1.99	-0.08	-1.02	3.17	81.74 %
R13121	D 39	7.40	.36	97.46	1.23	1.30	1.60	1.01	0.77	12.30	0.63	95.21 %
R13065	D 40	7.40	.11	91.89	3.44	4.68	1.74	1.69	0.28	3.86	0.21	91.83 %
R13032	E 2	7.40	.33	98.33	1.06	0.61	2.37	0.77	0.51	10.02	3.85	93.41 %
R13471	E 4	7.80	-.04	99.96	0.04	0.00	-.25	1.16	-0.33	0.43	2.73	94.56 %
R13475	E 6	7.90	.36	59.42	26.67	13.91	4.09	2.16	0.56	0.79	3.28	89.66 %
R13479	E 8	8.00	.42	49.17	23.84	26.99	4.96	2.85	0.32	-0.86	3.30	90.57 %
R13483	E 10	7.90	.03	5.86	31.16	62.99	8.17	2.12	-0.25	-0.60	3.47	86.72 %
R13392	E 12	8.20	.03	0.70	38.18	61.12	8.31	1.79	-0.11	-0.60	4.58	85.19 %
R13307	E 14	7.60	.03	4.78	41.36	53.87	7.68	1.95	-0.17	-0.86	4.36	84.43 %
R13310	E 16	7.70	.39	7.47	26.03	66.50	8.32	2.26	-0.34	-0.58	2.74	76.18 %
R13316	E 18	8.20	.40	91.52	4.13	4.35	1.74	1.36	1.14	9.36	0.73	96.59 %
R13321	E 20	7.90	.42	46.99	18.76	34.26	5.20	3.22	0.20	-1.41	2.15	90.55 %
R13323	E 22	7.70	.07	0.70	34.10	65.20	8.40	1.84	-0.18	-0.57	5.16	84.44 %
R13376	E 26	7.40	.36	53.44	21.95	24.61	4.32	2.71	0.35	-0.63	4.92	91.12 %

Lab. no.	Geol. no.	pH	Eh (volts)	Sand (%)	Silt (%)	Clay (%)	Mean (ϕ)	Std. dev. (ϕ)	Skew	Kurt.	CO_2 (%)	Total
R13109	E 28	7.60	.06	13.05	48.70	38.25	6.80	2.20	0.09	-1.25	5.97	84.21 %
R13110	E 30	7.50	.35	82.59	13.84	3.57	2.86	1.40	0.78	2.96	5.55	89.26 %
R13113	E 32	7.60	.37	77.84	16.42	5.74	3.11	1.41	0.69	2.73	5.31	90.51 %
R13116	E 34	7.70	.41	96.33	2.52	1.15	2.14	0.86	1.29	14.17	3.40	94.47 %
R13369	E 39	7.30	.06	1.75	55.05	43.20	7.29	1.92	-0.02	-1.06	2.92	81.30 %
R13214	E 40	7.40	.23	77.26	11.93	10.81	2.57	1.90	0.78	1.99	0.35	88.09 %
R13126	E 41	7.50	.35	6.77	55.76	37.47	6.79	2.01	0.12	-1.08	1.29	87.58 %
R13082	F 1	7.50	.34	97.84	1.29	0.88	1.70	0.76	1.74	26.80	1.87	93.88 %
R13083	F 3	7.70	.16								5.37	84.87 %
R13034	F 5	7.80	.34	81.57	11.49	6.95	2.60	1.76	0.35	2.53	4.52	93.86 %
R13477	F 7	8.00	.35	43.73	29.17	27.10	5.13	2.80	0.28	-0.87	2.40	96.14 %
R13297	F 9	8.00	.00	0.23	29.42	70.35	8.68	1.61	-0.13	-0.53	5.61	84.32 %
R13485	F 11	8.00	.35	0.62	32.71	66.67	8.52	1.72	-0.20	-0.22	2.92	88.69 %
R13390	F 13	7.70	.18	0.58	32.31	67.11	8.54	1.66	-0.15	-0.26	3.95	87.63 %
R13094	F 15	7.60	.38	21.06	18.01	60.93	7.38	3.16	-0.33	-0.92	9.10	81.19 %
R13383	F 17	8.10	.39	51.17	27.10	21.73	3.82	3.38	-0.04	-0.45	5.36	92.52 %
R13100	F 19	8.20	.03	0.84	41.80	57.35	7.86	1.77	-0.15	-0.85	5.83	83.18 %
R13241	F 21	7.70	.40	57.88	16.42	25.71	4.15	3.42	0.29	-0.98	0.79	92.12 %
R13235	F 25	7.60	.34	14.12	42.14	43.74	6.81	2.59	-0.15	-0.87	6.19	83.09 %
R13232	F 27	7.40	.34	24.38	20.38	55.24	7.14	3.18	-0.24	-1.11	2.26	88.63 %
R13229	F 29	7.50	.38	10.81	28.84	60.35	7.71	2.44	-0.17	-1.16	4.07	85.22 %
R13227	F 31	7.50	.37	23.32	21.03	55.65	7.19	3.09	-0.23	-1.18	3.22	87.04 %
R13334	F 35	7.80	.32	87.09	10.33	2.58	2.70	1.32	0.84	4.35	0.38	94.54 %
R13362	F 41	7.50	.37	87.49	8.03	4.48	2.54	1.47	0.47	4.02	2.67	92.72 %
R13209	F 42	7.40	.02	2.44	56.07	41.48	7.27	1.87	0.08	-1.05	0.18	73.35 %
R13355	F 43	7.70	.33	89.33	6.20	4.47	2.69	1.20	1.16	8.01	0.58	95.03 %
R13073	F 44	7.30	.10	97.17	1.51	1.32	1.30	1.60	-0.52	5.04	3.51	97.68 %
R13287	G 2	8.10	.07	31.57	21.54	46.89	5.04	4.83	-0.31	-1.09	5.93	84.23 %
R13472	G 4	7.80	.35	89.93	6.33	3.75	2.60	1.24	0.89	5.73	4.28	95.83 %
R13085	G 6	7.80	.44	42.77	25.93	31.30	5.29	2.98	0.22	-1.17	3.55	85.61 %
R13037	G 8	7.90	.32	21.57	24.43	54.00	7.20	2.95	-0.18	-1.19	2.78	91.83 %
R13300	G 10	7.90	.04	1.05	38.70	60.25	8.02	1.68	-0.16	-0.79	7.92	84.04 %
R13041	G 12	7.80	.36	3.58	27.16	69.26	8.50	1.98	-0.36	-0.06	3.50	91.87 %
R13388	G 14	7.60	.11	0.88	30.66	68.46	8.52	1.76	-0.21	-0.33	5.98	84.54 %
R13311	G 16	7.40	.43	90.17	5.70	4.13	1.70	1.80	0.16	2.58	2.97	91.13 %
R13317	G 18	7.80	.42	83.17	9.50	7.33	2.70	1.51	0.59	4.27	1.07	95.51 %
R13243	G 20	8.20	.45	95.80	2.11	2.08	1.61	1.66	-0.32	3.84	1.41	94.95 %
R13324	G 22	7.80	.20	25.59	22.56	51.84	6.68	3.69	-0.36	-0.38	6.26	89.91 %
R13104	G 24	7.70	.04	11.63	27.96	60.41	7.92	2.31	-0.25	-0.74	5.68	80.79 %
R13107	G 26	7.70	.36	43.50	31.57	24.93	4.66	2.61	0.26	-0.76	6.38	86.01 %
R13328	G 28	7.60	.40	40.47	20.41	39.12	5.66	3.21	0.03	-1.53	5.57	89.86 %
R13330	G 30	7.60	.06	0.47	28.20	71.33	8.76	1.57	-0.21	0.08	3.58	84.86 %
R13332	G 32	7.60	.06	0.34	32.26	67.40	8.63	1.63	-0.15	-0.34	3.17	85.29 %
R13057	G 34	7.50	.30	32.33	21.49	46.19	6.26	3.11	-0.07	-1.49	3.29	92.60 %
R13118	G 36	7.60		80.83	11.97	7.19	2.83	1.45	0.88	3.94	3.16	91.71 %
R13066	G 41	7.40	.35	34.76	31.25	33.99	5.49	3.32	-0.14	-0.58	2.99	88.85 %
R13491	G 42	7.40	.33	90.34	5.71	3.95	3.07	1.08	0.49	7.66	0.25	101.75 %
R13360	G 43	7.00	.03	4.55	54.59	40.86	6.99	2.01	-0.03	-1.13	3.76	83.25 %
R13204	G 44	7.10	.33	97.54	1.20	1.26	2.11	0.88	0.63	14.61	0.12	95.00 %
R13508	G 45	7.10	.14	99.26	0.43	0.31	1.97	0.63	1.08	21.75	0.09	99.73 %

Lab. no.	Geol. no.	pH	Eh (volts)	Sand (%)	Silt (%)	Clay (%)	Mean (ϕ)	Std. dev. (ϕ)	Skew	Kurt.	CO_2 (%)	Total
R13289	H 3	7.60	.18	73.24	22.69	4.07	3.48	1.28	0.76	2.49	5.27	89.99 %
R13473	H 5	7.60	.05	7.43	48.55	44.02	7.09	2.11	0.03	-1.22	4.56	85.41 %
R13293	H 7	7.80	.44	36.58	24.41	39.01	5.81	3.04	0.09	-1.39	1.60	88.74 %
R13087	H 9	8.00	.31	35.08	16.39	48.54	6.13	3.30	-0.07	-1.59	9.64	82.22 %
R13302	H 11	7.90	.05	0.71	40.82	58.47	7.95	1.62	-0.15	-0.63	5.83	81.71 %
R13092	H 13	7.90	.37	4.07	31.07	64.85	8.34	1.92	-0.27	-0.17	6.80	83.04 %
R13386	H 15	7.60	.39	55.92	14.16	29.91	4.57	3.37	0.24	-1.14	1.51	97.16 %
R13044	H 17	7.65	.39	61.69	18.20	20.11	3.64	2.74	0.49	-0.16	4.97	93.05 %
R13045	H 19	7.90	.40	23.87	31.62	44.51	6.35	3.09	-0.16	-1.10	1.93	93.79 %
R13047	H 21	8.20	.44	93.34	3.41	3.25	1.82	1.16	1.69	14.25	0.39	98.35 %
R13238	H 23	7.80	.42	80.90	7.75	11.34	2.27	2.03	0.48	2.62	3.30	92.95 %
R13051	H 25	7.60	.03	0.97	30.11	68.92	8.57	1.75	-0.28	0.07	4.37	84.36 %
R13233	H 27	7.60	.37	66.21	11.66	22.13	3.73	2.60	0.61	0.21	1.50	91.23 %
R13375	H 29	7.80	.05	0.63	27.31	72.06	8.78	1.58	-0.21	0.01	2.61	84.91 %
R13055	H 31	7.60	.10	1.40	31.49	67.11	8.53	1.74	-0.24	-0.04	2.13	93.67 %
R13226	H 33	7.60	.02	0.40	27.70	71.90	8.69	1.54	-0.15	0.05	2.59	70.55 %
R13224	H 35	7.60	.08	0.50	29.56	69.95	8.69	1.63	-0.20	-0.15	3.77	82.12 %
R13220	H 37	7.50	.36	73.68	13.07	13.24	3.31	2.25	0.79	1.72	3.43	86.40 %
R13122	H 39	5.10	.46	89.04	7.98	2.98	2.89	1.11	0.73	6.82	4.42	91.39 %
R13071	H 43	7.40	.38	28.12	22.93	48.94	6.54	3.14	-0.23	-1.12	1.35	89.99 %
R13353	H 45	7.40	.31	97.38	1.28	1.34	1.73	1.06	0.36	8.06	0.15	94.92 %
R13077	H 46	7.30	.16	98.93	0.69	0.38	1.56	0.78	0.84	11.61	0.04	97.90 %
R13084	I 4	7.70	.36	36.23	48.86	14.92	5.34	2.29	0.54	-0.05	4.15	81.21 %
R13476	I 6	7.90	.00	20.96	41.50	37.53	6.15	2.74	-0.02	-1.02	4.54	88.27 %
R13038	I 8	7.80	.09	2.16	43.73	54.11	7.82	1.80	-0.13	-0.82	3.36	83.06 %
R13301	I 10	7.30	.22								7.23	82.11 %
R13304	I 12	8.00	.15	0.74	39.97	59.29	8.05	1.63	-0.12	-0.85	5.53	82.51 %
R13308	I 14	8.00	.03	0.76	40.56	58.68	7.95	1.69	-0.13	-0.82	5.97	82.13 %
R13312	I 16	8.30	.39	44.15	10.84	45.01	5.63	3.53	0.08	-1.71	1.07	91.83 %
R13319	I 18	7.70	.39	33.87	19.68	46.45	6.06	3.31	-0.06	-1.56	0.58	90.06 %
R13322	I 20	7.70	.08	0.98	35.46	63.56	8.37	1.75	-0.16	-0.32	5.14	85.26 %
R13325	I 22		.30	41.94	20.29	37.77	5.43	3.32	0.08	-1.56	2.85	93.48 %
R13050	I 24	7.80	.39	65.61	8.51	25.89	3.98	3.27	0.48	-0.75	1.36	91.57 %
R13377	I 26	7.50	.03	0.72	32.04	67.24	8.49	1.75	-0.26	0.07	3.87	81.70 %
R13052	I 28	7.80	.34	68.15	9.27	22.58	3.51	2.79	0.63	0.00	1.30	98.23 %
R13111	I 30	7.60	.06	1.01	19.79	79.20	9.00	1.60	-0.41	0.87	2.07	86.81 %
R13114	I 32	7.60	.00	1.26	25.01	73.73	8.81	1.56	-0.32	0.92	3.39	82.66 %
R13372	I 34	7.80	.18	48.72	9.26	42.02	5.13	3.64	0.13	-1.70	1.97	94.70 %
R13335	I 36	7.60	.04	2.21	23.85	73.94	8.73	1.76	-0.37	0.40	3.92	84.71 %
R13062	I 38	8.10	.34	62.56	24.62	12.82	3.97	2.13	0.61	1.13	4.69	88.07 %
R13215	I 40	7.20	.41	91.70	5.24	3.07	2.30	1.31	0.87	7.41	0.97	94.12 %
R13361	I 43	7.60	.22	79.36	16.33	4.31	3.44	1.30	0.10	5.93	4.68	90.93 %
R13205	I 44	7.60	.32	96.62	1.85	1.54	1.90	1.02	0.91	11.47	0.03	94.09 %
R13075	I 45	7.60	.12	100.00	0.00	0.00	1.87	0.49	0.02	0.59	0.04	95.76 %
R13033	J 3	7.60	.40	99.18	0.42	0.40	2.39	0.60	0.15	7.01	2.51	94.29 %
R13291	J 5	7.60	-.01	2.51	67.81	29.67	6.43	1.57	0.25	-0.57	4.03	80.48 %
R13478	J 7	7.80	.32	57.08	28.00	14.92	3.93	2.45	0.42	-0.28	4.15	93.24 %
R13298	J 9	8.10	.00	3.65	52.97	43.38	7.23	1.88	0.06	-0.99	4.18	82.78 %
R13486	J 11	8.00	.33	7.26	35.45	57.29	7.96	2.21	-0.18	-0.84	0.29	91.05 %
R13306	J 13	8.10	.32	34.81	24.73	40.46	5.79	3.20	-0..01	-1.47	3.73	89.45 %

Lab. no.	Geol. no.	pH	Eh (volts)	Sand (%)	Silt (%)	Clay (%)	Mean (ϕ)	Std. dev. (ϕ)	Skew	Kurt.	CO_2 (%)	Total
R13387	J 15	7.80	.33	47.87	22.04	30.09	4.97	3.14	0.19	-1.34	1.72	94.15 %
R13384	J 17	8.30	.09	10.96	31.38	57.66	7.67	2.11	-0.28	-0.74	3.85	88.00 %
R13381	J 19	8.10	.00	3.15	34.80	62.05	8.25	1.86	-0.20	-0.24	3.70	87.74 %
R13242	J 21	7.60	.02	1.63	35.78	62.59	8.38	1.70	-0.14	-0.12	3.27	83.45 %
R13378	J 23	7.70	.03	2.77	40.55	56.68	7.95	1.68	-0.21	-0.30	4.83	81.74 %
R13327	J 25	7.70	.30	33.35	22.19	44.46	6.00	3.31	-0.11	-1.53	2.98	86.92 %
R13234	J 27	7.60	.23	7.50	35.84	56.67	7.73	1.85	-0.29	-0.16	3.94	80.51 %
R13230	J 29	7.70	.34	14.45	29.85	55.70	7.48	2.28	-0.23	-1.08	3.13	83.66 %
R13228	J 31	7.60	.29	3.30	20.44	76.27	8.84	1.70	-0.51	1.54	1.25	83.61 %
R13487	J 33	8.00	.05	1.50	23.53	74.97	8.81	1.71	-0.38	0.54	1.96	91.10 %
R13059	J 35	7.40	.06	0.93	28.18	70.89	8.76	1.60	-0.27	0.46	2.52	84.53 %
R13370	J 37	8.40	.35	0.43	26.46	73.11	8.74	1.66	-0.29	0.12	3.55	87.06 %
R13367	J 39	7.40	.19	0.18	35.93	63.89	8.45	1.77	-0.16	0.60	2.80	86.27 %
R13067	J 41	7.40	.38	96.51	2.07	1.42	1.98	0.85	2.05	25.29	0.33	97.92 %
R13506	J 44	7.10	.06	3.78	54.97	41.26	7.06	1.86	0.07	-0.90	3.47	85.66 %
R13200	J 46	7.30	.06	98.62	0.69	0.68	1.81	0.72	0.86	24.95	0.30	92.97 %
R13474	K 4	7.70	.02	89.67	5.47	4.86	3.18	1.03	1.23	11.25	3.81	95.29 %
R13035	K 6	8.10	-.05	30.54	60.48	8.98	4.82	1.62	0.65	2.22	4.34	83.11 %
R13481	K 8	7.40	-.01	1.20	69.90	28.90	6.54	1.87	0.35	-0.67	4.26	84.45 %
R13484	K 10	7.40	.01	2.75	50.35	46.90	7.48	1.78	0.02	-0.88	4.73	85.25 %
R13393	K 12	7.90	.01	5.97	50.10	43.92	7.15	1.98	0.06	-1.10	3.68	88.61 %
R13389	K 14	7.90	.35	55.92	19.14	24.94	4.16	2.83	0.37	-0.88	3.25	93.41 %
R13313	K 16	7.80	.29	11.50	37.77	50.73	7.30	2.15	-0.12	-1.11	4.35	87.29 %
R13318	K 18	7.90	.05	8.43	36.00	55.56	8.01	2.17	-0.23	-0.65	3.90	84.88 %
R13379	K 20	7.50	.01	4.12	43.19	52.69	7.96	2.01	-0.09	-0.79	3.82	82.26 %
R13103	K 22	7.80	-.01	3.92	49.87	46.21	7.51	1.79	-0.06	-0.70	5.01	81.14 %
R13105	K 24	7.70	-.02	3.96	44.87	51.17	7.71	1.79	-0.14	-0.61	5.44	80.40 %
R13108	K 26	7.70	.34	88.94	6.64	4.43	2.06	1.42	1.32	7.80	2.25	91.31 %
R13329	K 28	7.50	.02	3.30	40.77	55.93	7.87	1.76	-0.20	-0.46	4.19	85.67 %
R13331	K 30	7.50	.33	16.63	23.78	59.58	7.60	2.27	-0.31	-0.86	1.97	88.65 %
R13333	K 32	7.70	.00	6.82	23.46	69.72	8.45	2.00	-0.42	0.30	2.60	87.75 %
R13117	K 34	7.50	.05	0.98	29.06	69.96	8.62	1.66	-0.23	0.10	2.13	82.72 %
R13119	K 36	7.60	.04	0.95	26.93	72.12	8.75	1.60	-0.25	0.29	3.44	83.61 %
R13498	K 38	7.40	.01	0.54	30.86	68.60	8.61	1.64	-0.17	-0.21	2.97	85.81 %
R13495	K 40	7.60	.11	1.64	40.39	57.97	7.92	1.73	-0.20	-0.54	2.90	85.76 %
R13210	K 42	7.70	.35	94.47	3.73	1.80	2.05	0.97	1.81	16.98	0.07	96.94 %
R13128	K 43	7.70	.34	67.41	21.39	11.20	3.67	1.60	0.24	2.70	3.49	88.64 %
R13294	L 7	8.00	.00	95.48	3.13	1.39	2.37	0.98	0.82	6.36	2.92	95.40 %
R13299	L 9	7.60	-.06	5.94	60.43	33.63	6.74	1.87	0.22	-0.78	4.47	82.13 %
R13089	L 11	7.60	.01	6.69	45.98	47.34	7.48	1.89	-0.11	-0.70	4.09	81.97 %
R13391	L 13	7.90	.01	15.65	39.18	45.18	7.14	2.16	-0.11	-1.04	4.53	86.42 %
R13095	L 15	7.90	.02	8.12	42.31	49.57	7.48	1.97	-0.15	-0.77	4.44	84.43 %
R13098	L 17	7.80	.05	56.95	19.87	23.18	3.97	2.90	0.38	-0.94	4.28	88.25 %
R13101	L 19	7.60	.36	60.40	29.12	10.49	3.36	2.00	0.40	-0.30	5.39	88.06 %
R13048	L 21	7.60	.16	80.93	14.43	4.64	2.94	1.47	0.52	1.79	4.70	89.97 %
R13236	L 25	7.60	.31	85.20	9.86	4.94	2.54	1.44	0.98	4.52	1.85	90.90 %
R13054	L 29	7.50	-.01	5.81	44.72	49.46	7.48	2.00	-0.11	-0.98	5.66	83.46 %
R13374	L 31	7.50	.35	15.36	26.50	58.14	7.55	2.27	-0.28	-0.94	2.78	88.56 %
R13056	L 33	7.60	.04	3.99	28.46	67.55	8.48	1.84	-0.33	0.33	3.89	84.00 %
R13225	L 35	7.70	.36	53.84	16.46	29.71	4.40	3.49	0.27	-1.28	2.00	90.29 %

Lab. no.	Geol. no.	pH	Eh (volts)	Sand (%)	Silt (%)	Clay (%)	Mean (ϕ)	Std. dev. (ϕ)	Skew	Kurt.	CO_2 (%)	Total
R13221	L 37	7.40	.04	0.92	32.15	66.93	8.65	1.55	-0.13	0.04	5.54	83.68 %
R13123	L 39	7.60	.04	0.95	27.28	71.77	8.69	1.59	-0.26	0.49	4.24	83.14 %
R13363	L 41	7.90	.11	10.61	33.84	55.55	7.42	2.29	-0.17	-1.26	4.54	88.02 %
R13359	L 43	8.00	.31	68.69	15.14	16.17	3.58	2.45	0.63	0.53	4.89	93.83 %
R13074	L 44	7.80	.43	32.18	28.02	39.80	5.90	3.02	-0.00	-1.34	6.57	89.46 %
R13507	L 45	7.70	.43	89.61	6.73	3.67	2.49	1.32	1.04	6.22	0.85	99.93 %
R13482	M 8	7.90	.05	93.44	4.74	1.82	2.79	0.95	0.64	5.93	2.26	95.02 %
R13040	M 10	7.80	-.03	7.11	72.18	20.71	6.06	2.07	0.30	-0.19	13.18	80.20 %
R13305	M 12	7.70	.06	5.78	55.77	38.45	7.11	1.89	0.09	-0.89	11.37	80.94 %
R13043	M 14	7.70	.00	3.18	53.32	43.50	7.36	1.78	0.02	-0.77	11.60	79.63 %
R13314	M 16	7.90	.11	6.56	53.77	39.67	7.19	1.87	0.02	-0.79	10.50	81.19 %
R13320	M 18	8.10	.05	75.04	17.94	7.02	3.50	1.35	0.58	2.89	7.92	90.09 %
R13112	M 30	7.60	.31	100.00	0.00	0.00	1.69	0.57	-0.01	0.46	0.54	98.53 %
R13115	M 32	7.70	.02	11.03	42.76	46.21	6.93	2.60	-0.33	-0.26	8.63	82.27 %
R13373	M 34	7.60	.05	4.72	26.68	68.59	8.40	2.04	-0.37	-0.08	6.39	82.64 %
R13336	M 36	7.40	.04	1.32	45.26	53.42	7.88	1.70	-0.11	-0.80	0.00	82.69 %
R13063	M 38	7.60	.11	11.81	28.83	59.36	7.71	2.08	-0.34	-0.54	6.90	85.56 %
R13216	M 40	7.60	.05	0.56	32.46	66.98	8.59	1.58	-0.12	-0.09	8.46	74.00 %
R13069	M 42	7.50	.05	0.38	33.11	66.51	8.52	1.60	-0.13	-0.08	3.09	83.70 %
R13505	M 44	7.70	.11	1.95	50.15	47.90	7.48	1.85	-0.05	-0.99	4.99	87.62 %
R13201	M 46	7.30	.34	89.54	7.45	3.01	2.39	1.42	0.92	4.77	1.31	94.58 %
R13091	N 13	7.70	.14	97.71	1.40	0.89	2.19	0.80	1.13	11.16	0.18	90.52 %
R13096	N 15	7.70	.13	99.86	0.13	0.00	1.58	0.61	0.11	2.37	17.93	95.25 %
R13222	N 37	7.70	.10	13.73	51.61	34.66	6.10	2.32	-0.19	-0.55	2.15	82.26 %
R13124	N 39	7.80	.36	33.38	25.78	40.84	5.71	3.36	-0.04	-1.05	15.90	84.69 %
R13494	N 41	7.60	.02	0.45	31.64	67.91	8.60	1.62	-0.14	-0.33	5.84	87.34 %
R13129	N 43	7.90	.25	1.33	40.76	57.92	7.99	1.59	-0.17	-0.39	2.92	81.11 %
R13352	N 45	7.70	.05	5.74	44.55	49.71	7.34	2.11	-0.07	-1.21	4.98	86.08 %
R13347	N 47	7.60	.36	99.00	0.50	0.50	1.79	0.96	-0.71	12.88	1.52	99.51 %
R13120	O 36	7.60	.26	100.00	0.00	0.00	-1.08	2.18	0.13	-1.66	6.79	92.01 %
R13499	O 38	7.70	.30	81.51	13.29	5.21	2.57	1.66	0.67	1.85	4.69	97.15 %
R13125	O 39	7.90	.32	98.91	0.77	0.33	1.66	0.88	0.77	6.76	4.98	96.77 %
R13496	O 40	7.65	.38	50.52	21.37	28.11	4.65	3.25	0.26	-1.26	19.50	96.71 %
R13211	O 42	7.40	.07	2.78	39.49	57.74	7.85	1.86	-0.21	-0.75	13.64	78.02 %
R13206	O 44	7.60	.34	28.01	22.24	49.75	6.35	3.27	-0.19	-1.42	9.78	82.08 %
R13078	O 46	7.50	.11	3.60	53.41	42.99	7.23	1.93	0.01	-1.03	12.91	84.26 %
R13079	O 48	7.70	.39	99.86	0.06	0.08	2.16	0.55	0.18	5.35	0.08	93.01 %
R13488	P 38	7.80	.23	79.86	14.87	5.26	2.52	1.68	0.77	2.09	3.83	95.81 %
R13364	P 41	7.40	.39	59.23	18.85	21.92	4.15	2.67	0.37	-0.40	4.72	90.44 %
R13358	P 43	7.50	.23	2.67	31.25	66.08	8.42	1.96	-0.29	-0.29	14.73	78.13 %
R13348	P 47	7.70	.39	87.71	6.32	5.97	2.52	1.36	1.03	6.56	1.55	96.07 %
R13497	Q 38	7.60	.29	83.06	13.02	3.92	2.67	1.55	0.66	2.12	5.91	98.85 %
R13368	Q 39	7.70	.37	87.89	8.13	3.98	2.18	1.45	1.08	5.56	2.33	98.24 %
R13217	Q 40	7.70	.36	69.92	14.10	15.98	3.14	2.65	0.63	0.57	3.28	93.07 %
R13068	Q 41	7.90	.40	85.76	10.47	3.78	3.06	1.23	0.78	4.81	6.08	90.17 %
R13492	Q 42	8.00	.36	100.00	0.00	0.00	1.02	0.53	-0.57	3.09	3.00	97.25 %
R13504	Q 44	7.80	.19	83.35	11.44	3.20	3.00	1.30	0.61	3.50	4.41	96.99 %
R13196	Q 48	7.50	.36	80.63	16.51	2.86	3.19	1.30	0.40	2.11	2.18	95.21 %
R13365	R 41	7.50	.07	4.80	45.30	49.90	7.41	1.99	-0.09	-1.05	10.05	87.30 %
R13493	R 42	7.70	.05	40.63	37.03	22.34	4.88	2.62	0.11	-1.04	5.78	92.74 %

Lab. no.	Geol. no.	pH	Eh (volts)	Sand (%)	Silt (%)	Clay (%)	Mean (ϕ)	Std. dev. (ϕ)	Skew	Kurt.	CO_2 (%)	Total
R13130	R 43	7.75	.08	9.18	46.81	44.01	7.13	2.03	-0.04	0.99	8.94	93.43 %
R13503	R 44	7.50	.39	96.69	1.72	1.59	1.60	1.30	1.03	14.03	1.12	98.74 %
R13076	R 45	7.40	.09	3.94	58.70	37.36	7.00	1.90	0.11	-0.93	22.27	80.29 %
R13489	S 38	7.60	.33	53.96	20.89	25.15	4.14	2.88	0.35	-0.90	4.44	94.73 %
R13366	S 41	7.90	.01	59.13	21.28	12.59	3.87	2.29	0.48	0.35	8.69	88.84 %
R13212	S 42	7.60	.01	94.52	2.83	2.65	1.62	1.15	1.71	15.46	0.00	99.09 %
R13357	S 43	7.70	.40	83.69	7.98	8.34	2.46	1.60	1.00	4.38	3.00	93.55 %
R13207	S 44	7.40	.39	75.47	12.53	12.01	2.83	1.83	0.74	1.85	2.32	95.03 %
R13197	S 48	7.60	.29	99.33	0.67	0.00	1.50	0.67	-1.53	14.66	1.52	93.01 %
R13490	T 38	7.70	.40	79.91	11.81	8.28	2.56	1.71	0.98	3.33	3.97	95.97 %
R13064	T 39	7.40	.34	98.56	0.68	0.76	1.93	0.63	1.94	33.94	0.00	98.03 %
R13218	T 40	7.50	.33	73.88	15.67	10.45	2.76	1.87	0.76	1.60	2.43	93.27 %
R13127	T 41	7.90	.33	78.80	15.03	6.17	3.02	1.53	0.65	2.30	2.17	94.40 %
R13070	T 42	7.80	.31	53.63	22.36	24.01	4.10	2.87	0.34	-0.79	5.55	87.70 %
R13500	T 43	7.70	.03	0.79	53.57	45.64	7.64	1.57	0.03	-0.63	8.09	83.92 %
R13502	T 44	7.40	.00	91.88	4.15	3.97	1.92	1.28	1.40	9.88	0.55	99.27 %
R13351	T 45		.40	76.90	17.78	5.32	2.84	1.61	0.57	1.51	1.41	94.60 %
R13346	T 48	7.60	.36	99.52	0.48	0.00	2.08	0.88	-0.79	4.50	1.22	98.92 %
R13081	T 50	7.40	.07	6.76	75.83	17.41	6.18	2.09	0.42	-0.69	12.31	86.45 %
R13213	U 42	7.70	.38	94.58	2.89	2.53	1.97	1.23	0.79	7.81	2.07	95.05 %
R13131	U 43	7.50	.38	97.06	1.66	1.28	0.11	2.69	-0.23	-0.54	4.03	94.31 %
R13208	U 44	7.90	.30	64.89	15.20	19.91	3.80	2.67	0.49	-0.26	3.28	90.48 %
R13350	U 45											97.51 %
R13202	U 46	7.40	.09	92.52	3.78	3.71	1.97	1.58	0.28	5.89	0.51	93.94 %
R13198	U 48	7.60	.35	61.51	23.04	15.45	3.72	2.52	0.45	0.03	1.79	95.56 %
R13344	U 49	7.80	.16	99.98	0.02	0.00	1.15	0.92	-1.37	10.99	5.45	93.85 %
R13194	U 50	7.50	.42	97.76	1.50	0.74	2.02	0.85	0.63	6.55	0.63	95.44 %
R13072	V 43	7.70	.07	10.65	47.52	41.83	6.95	2.13	0.03	-1.18	15.46	84.46 %
R13501	V 44	7.70	.30	89.86	6.59	3.55	2.17	1.39	1.13	6.53	0.71	96.19 %
R13349	V 45	7.60	.31	95.82	2.14	2.04	1.70	1.17	1.07	11.91	0.85	98.44 %
R13345	V 48	7.60	.31	87.24	9.32	3.44	2.35	1.49	0.52	2.28	0.76	97.65 %
R13195	V 49	7.40	.36	68.35	26.18	5.47	3.71	1.37	0.35	2.42	2.58	93.54 %
R13356	W 43	7.80	.29	96.25	1.90	1.86	1.99	0.90	1.73	19.42	0.56	96.89 %
R13203	W 46	7.10	.06	6.82	61.54	31.63	6.72	1.92	0.16	-0.87	10.00	79.40 %
R13080	W 48	8.20	.27	50.20	36.32	13.47	4.66	1.86	0.69	1.30	2.62	91.28 %
R13199	X 48	8.10	.37	87.25	9.96	2.79	2.81	1.23	0.54	3.36	1.37	94.79 %

APPENDIX 3

ELEMENTAL DISTRIBUTIONS

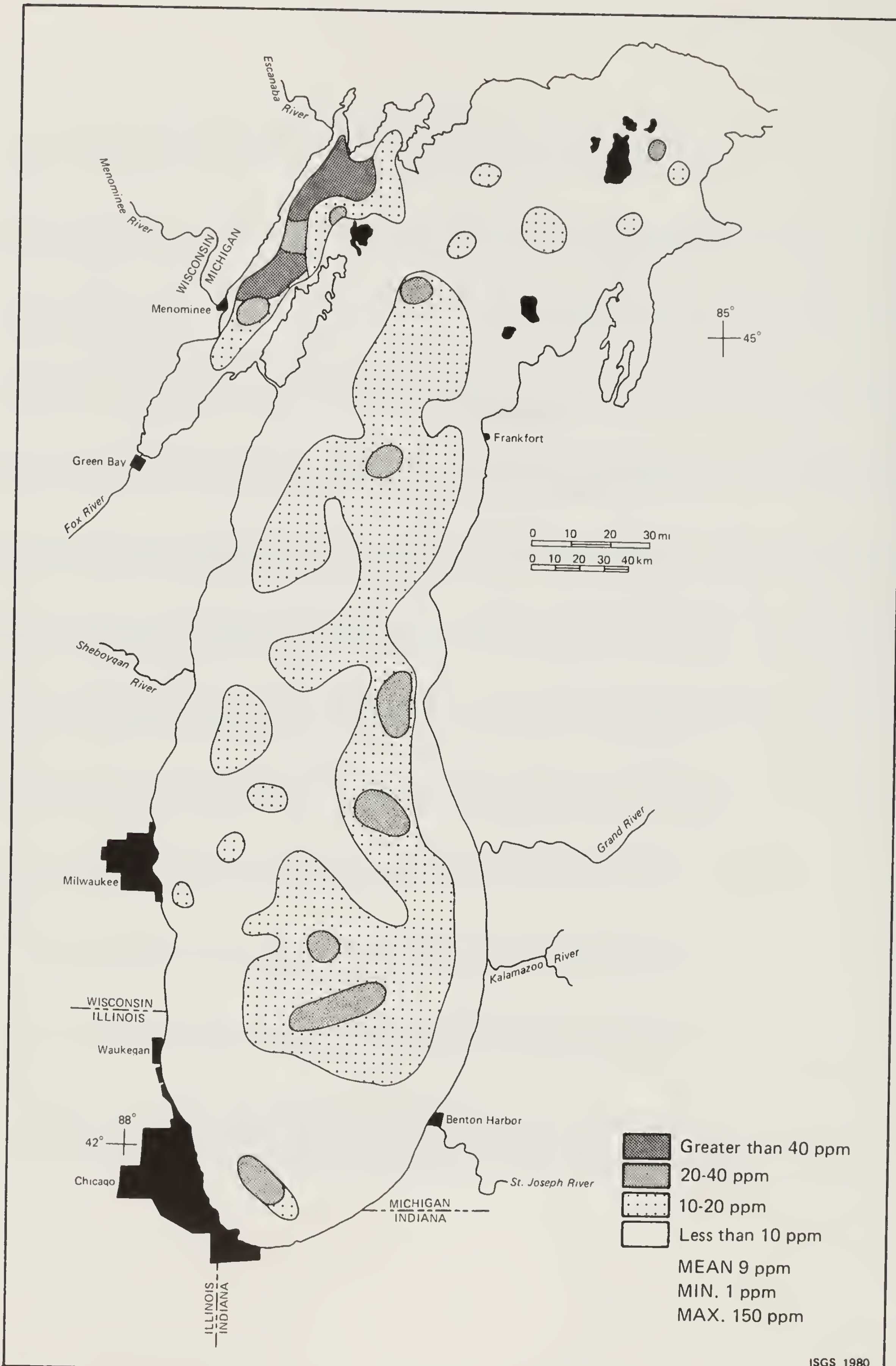

Figure A. Arsenic distribution in the upper 3 cm of Lake Michigan sediments.

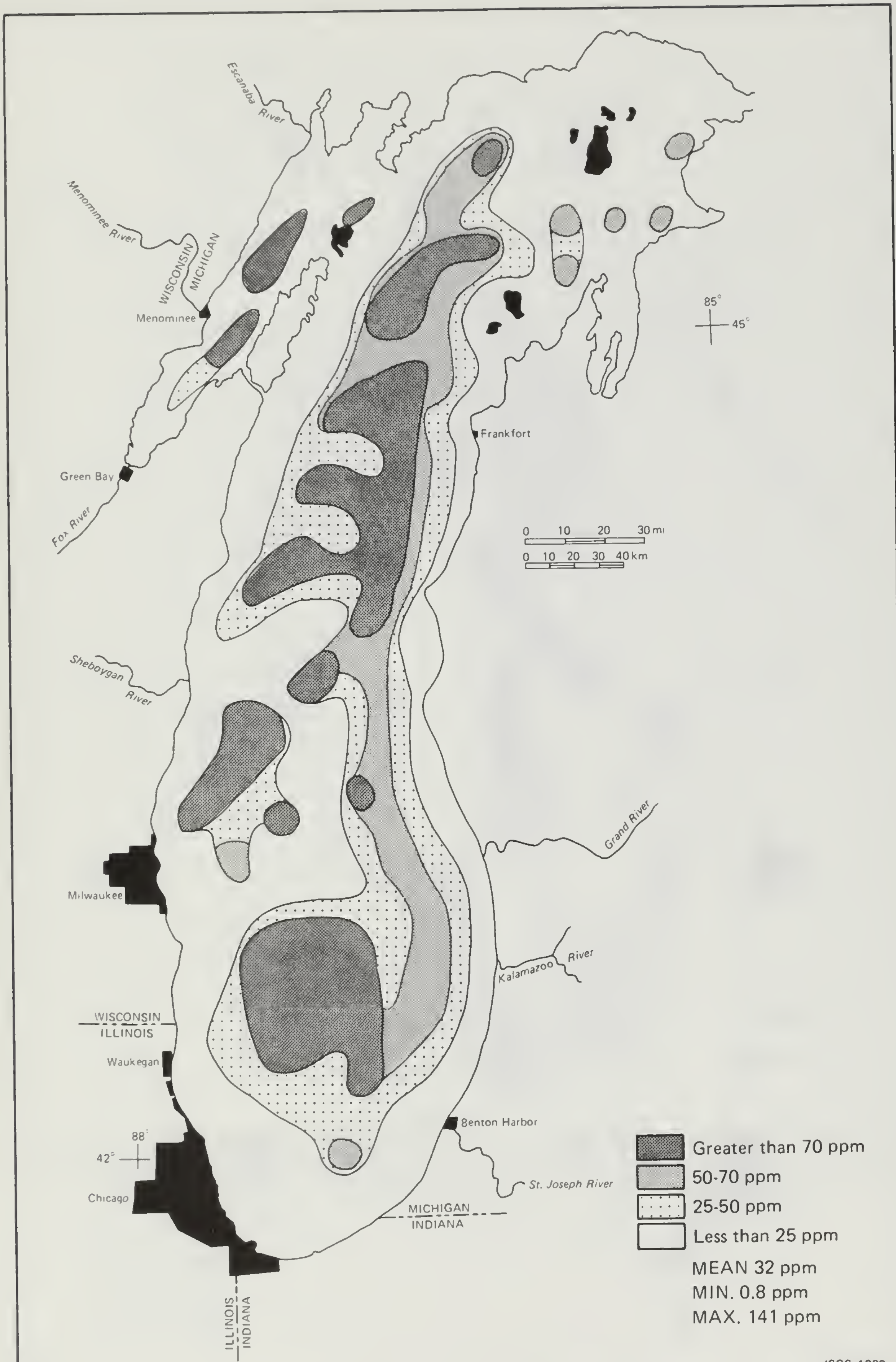

Figure B. Bromine distribution in the upper 3 cm of Lake Michigan sediments.

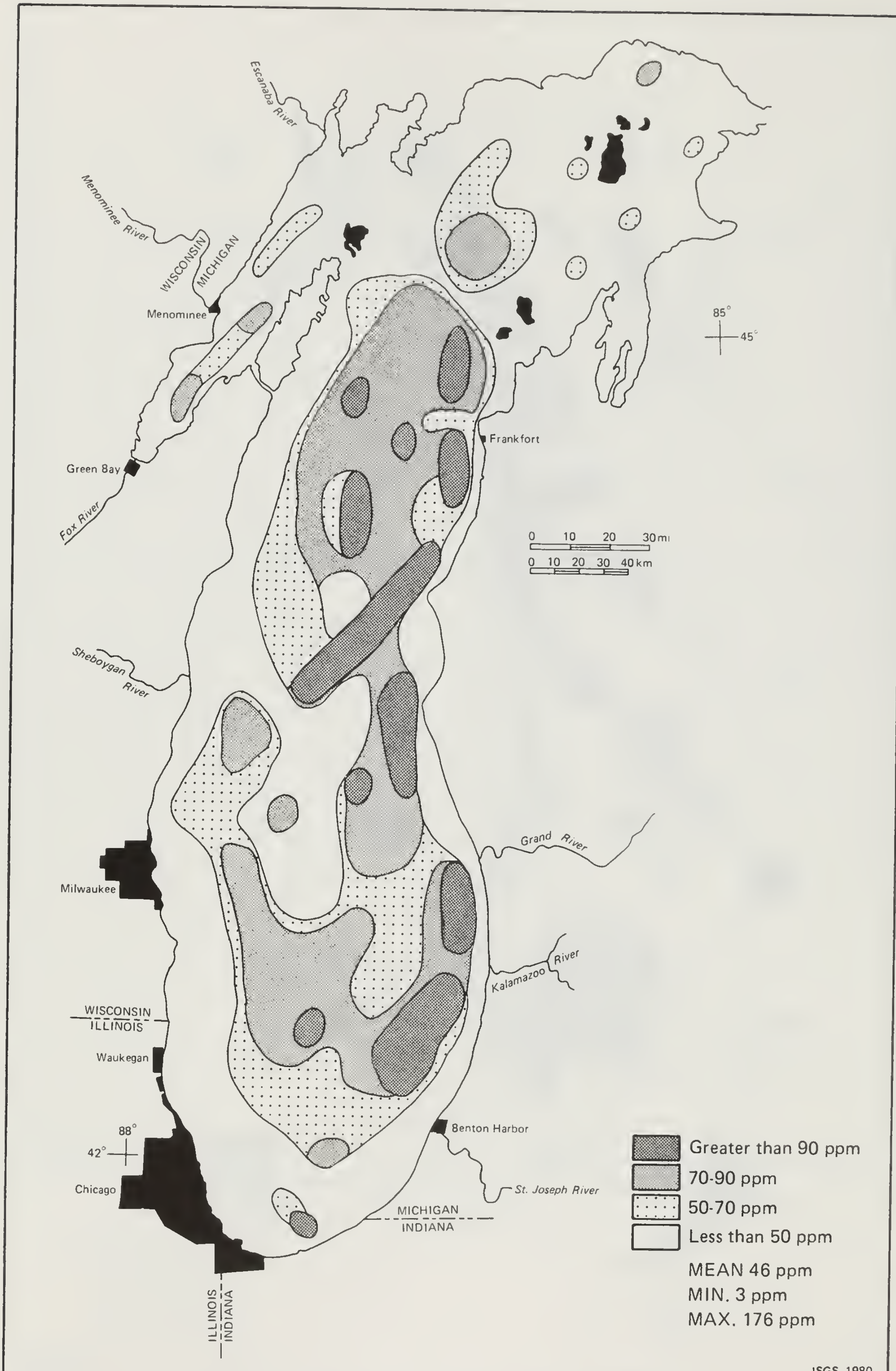

Figure C. Chromium distribution in the upper 3 cm of Lake Michigan sediments.

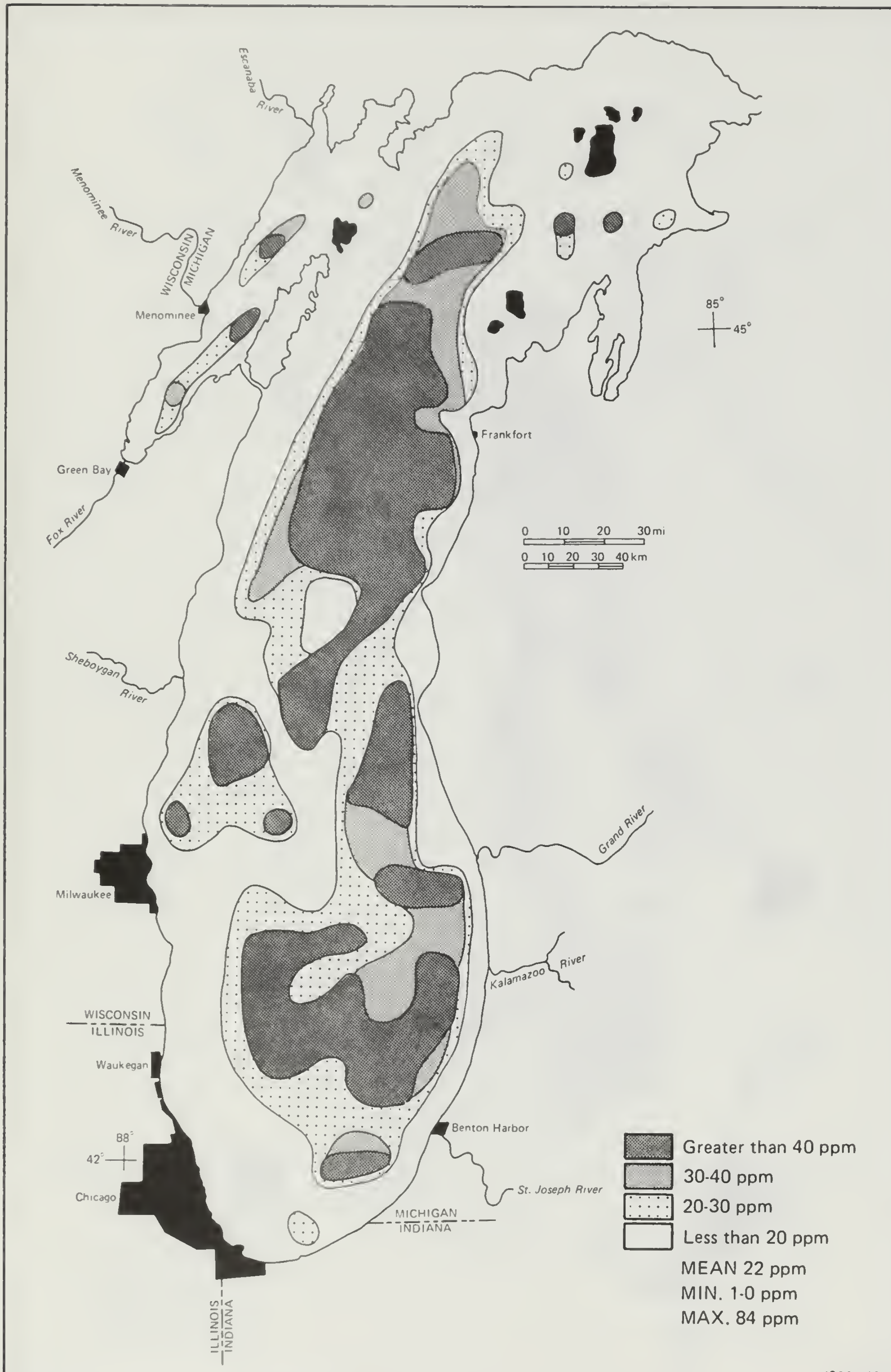

Figure D. Copper distribution in the upper 3 cm of Lake Michigan sediments.

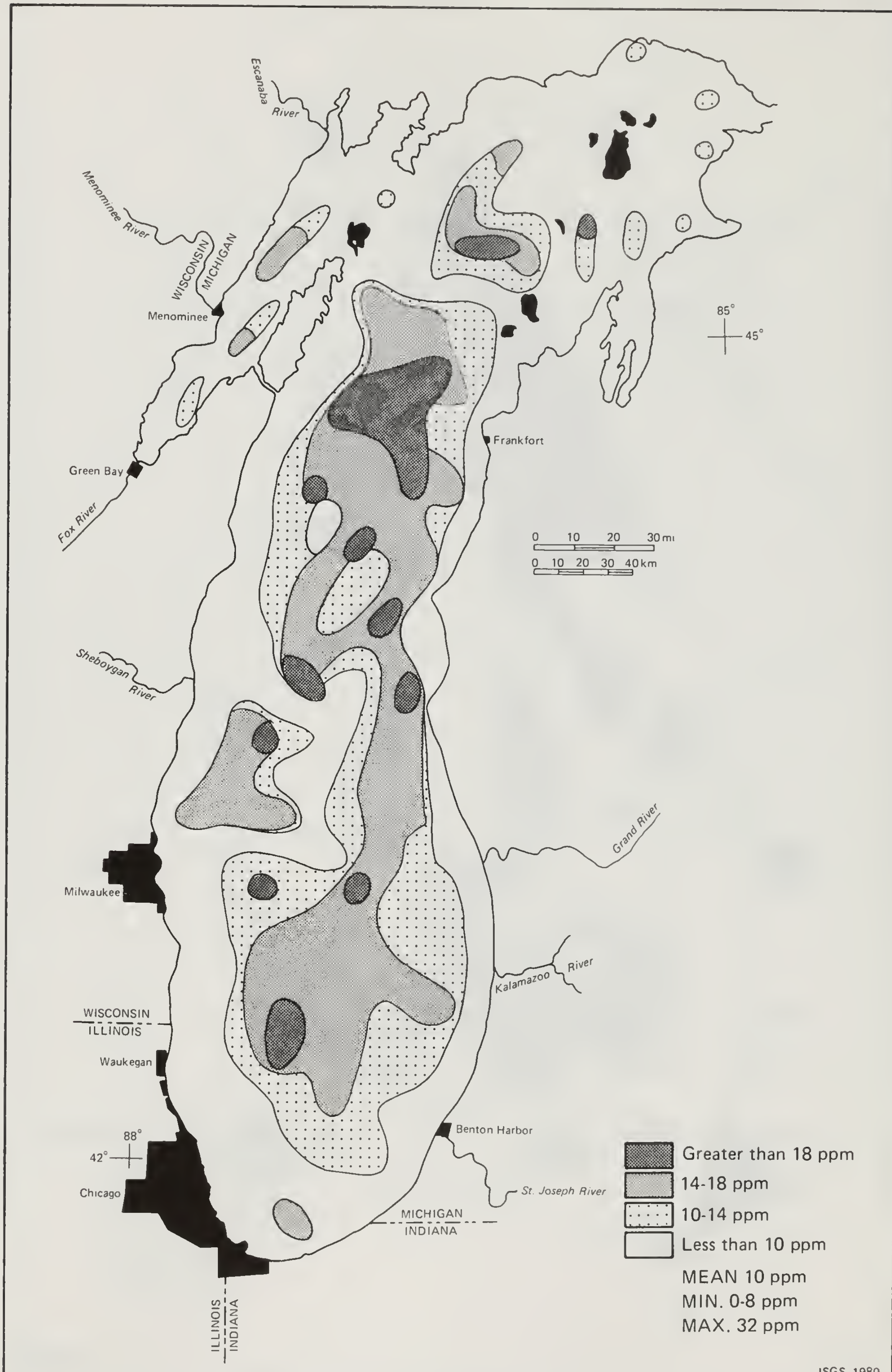

Figure E. Gallium distribution in the upper 3 cm of Lake Michigan sediments.

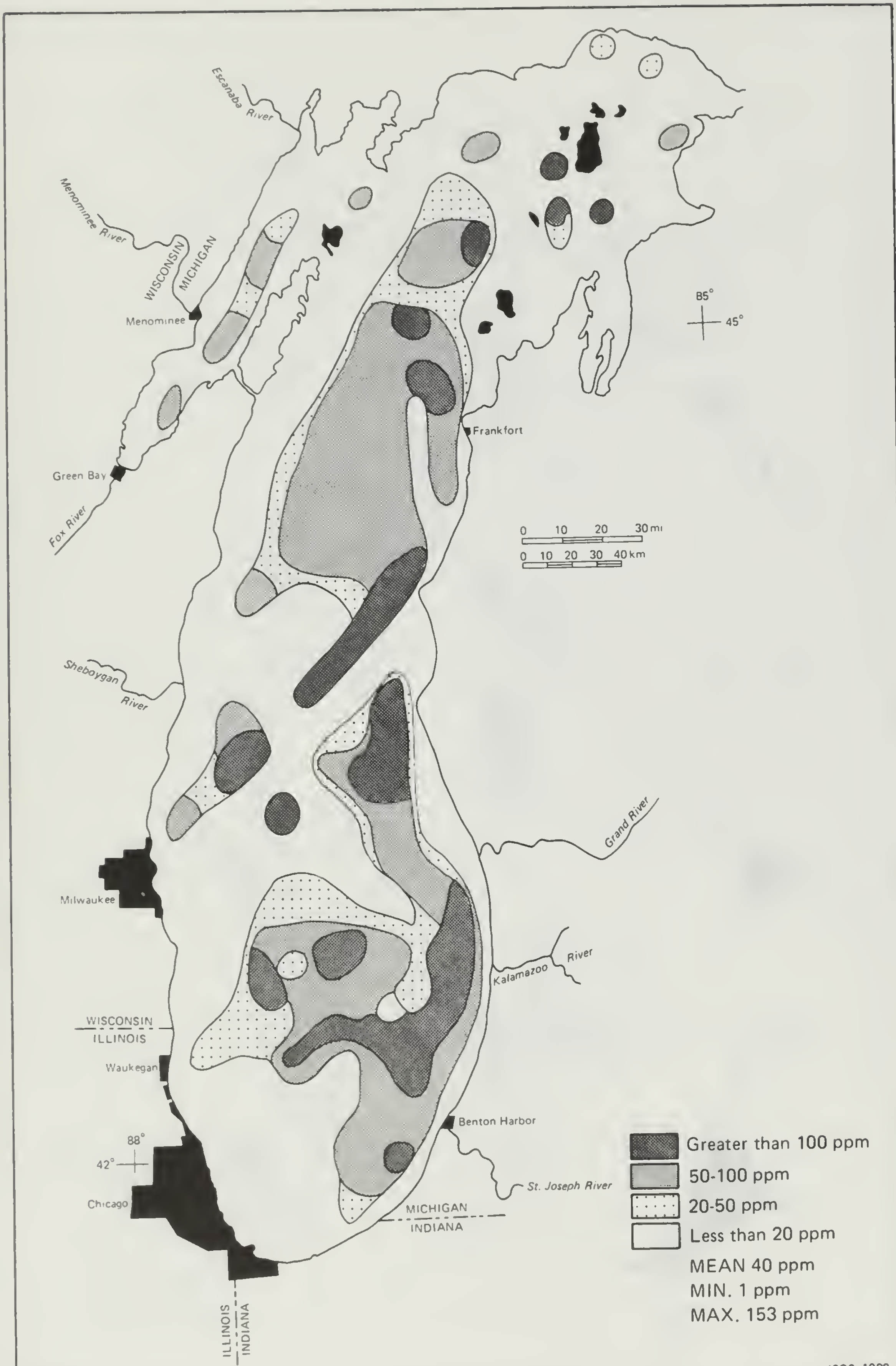

Figure F. Lead distribution in the upper 3 cm of Lake Michigan sediments.

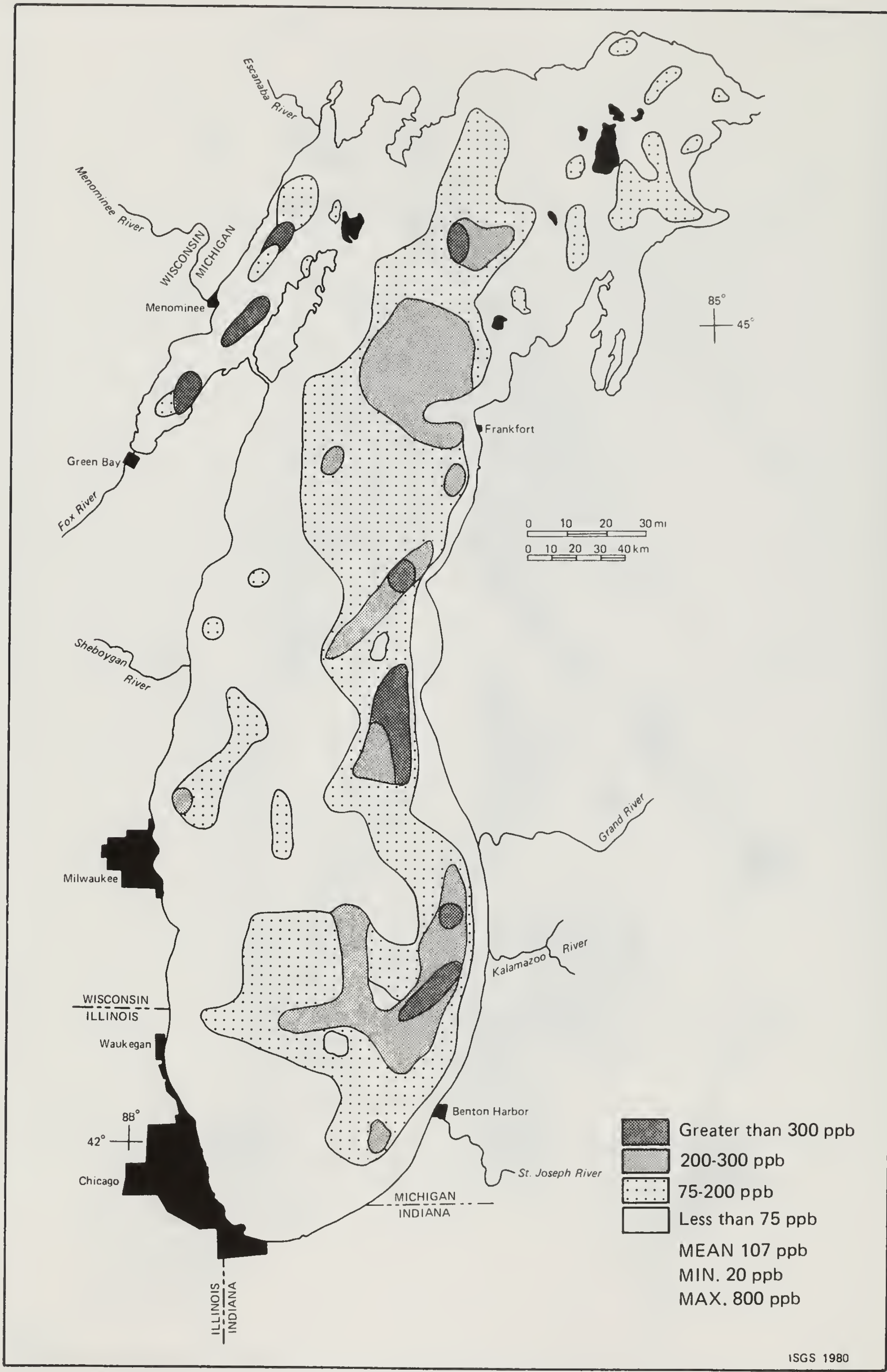

Figure G. Mercury distribution in the upper 3 cm of Lake Michigan sediments.

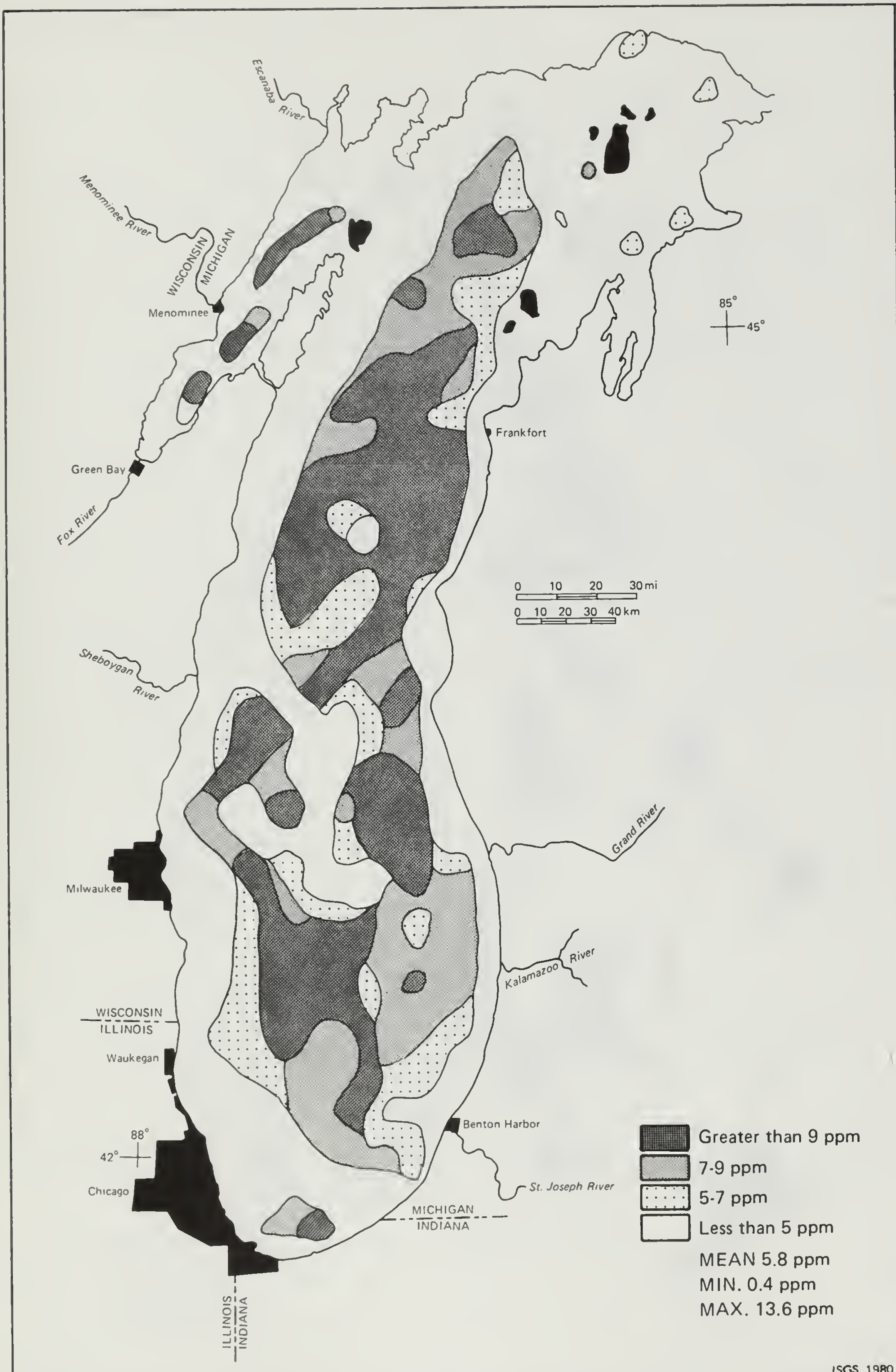

Figure H. Thorium distribution in the upper 3 cm of Lake Michigan sediments.

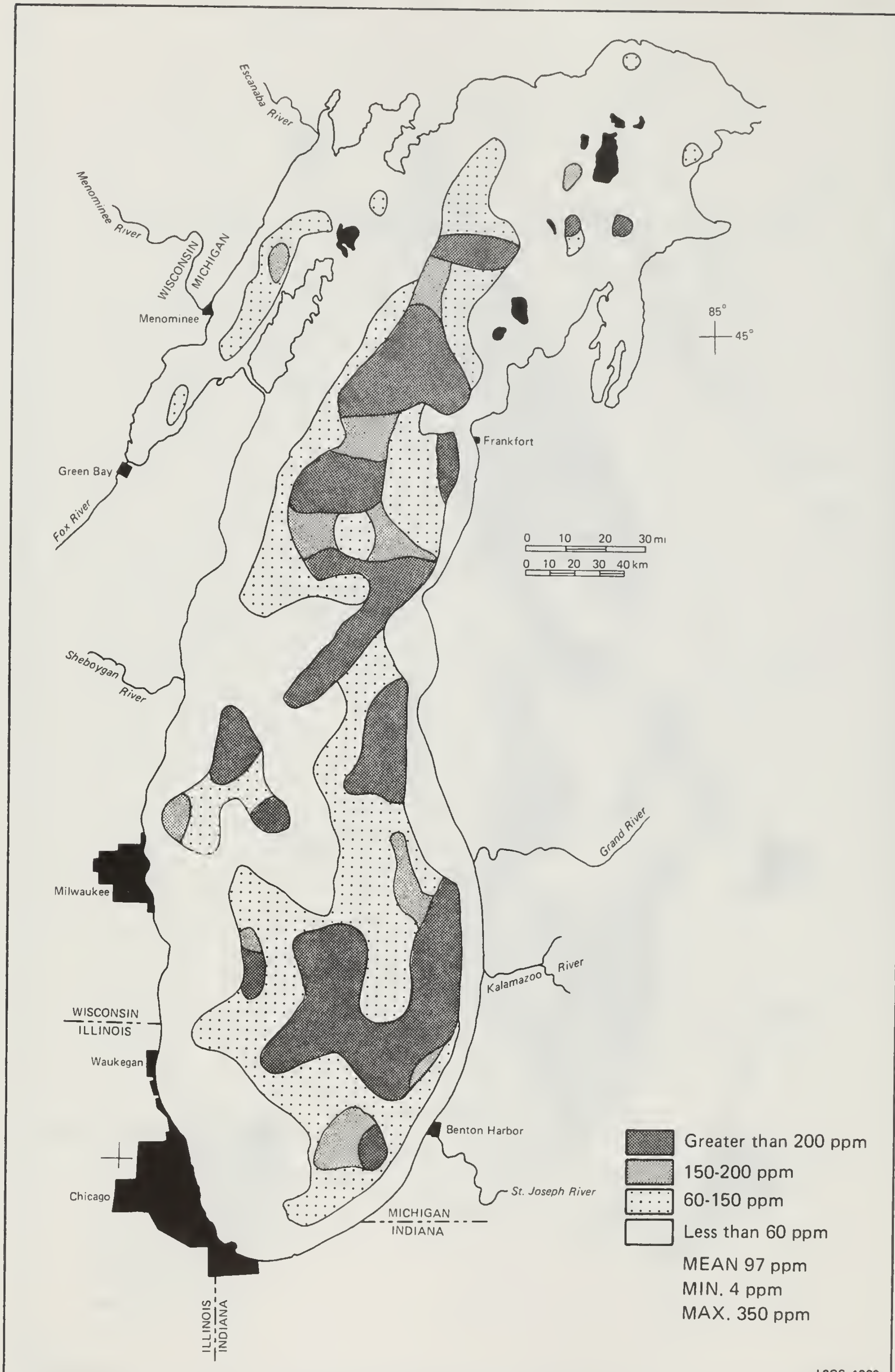

Figure 1. Zinc distribution in the upper 3 cm of Lake Michigan sediments.

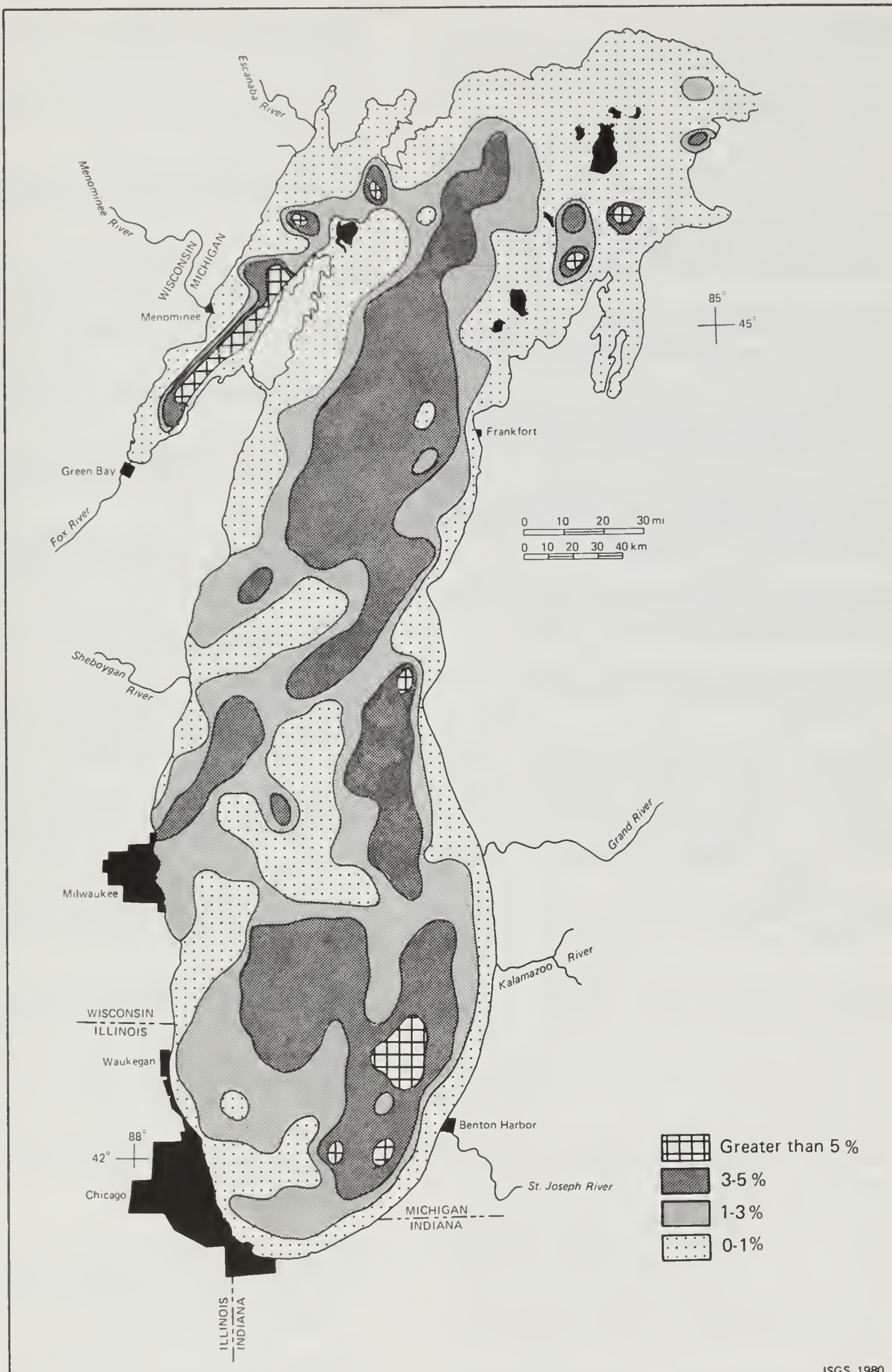

Figure J. Organic carbon distribution in the upper 3 cm of Lake Michigan sediments.

REFERENCES

Agemian, H., and A.S.Y. Chau, 1975, A method for determination of mercury in sediments by the automated coal vapor atomic adsorption technique after digestion; Analytica Chimica Acta, v. 75, p. 297-304.

Agemian, H., and A.S.Y. Chau, 1976, Evaluation of extraction techniques for the determination of metals in aquatic sediments: The Analyst, v. 101, no. 1207, p. 761-767.

Andren, A. W., and R. C. Harriss, 1975, Observations on the association between Hg and organic matter dissolved in natural waters: Geochimica et Cosmochimica Acta, v. 39, p. 1253-1257.

Ayers, J. C., D. C. Chandler, G. H. Lauff, C. F. Powers, and E. B. Henson, 1958, Currents and water masses of Lake Michigan: Great Lakes Research Institute, Publication no. 3, Ann Arbor, MI, 169 p.

Baker, W. E., 1973, The role of humic acids from Tasmanian Podzolic soils in mineral degradation and metal mobilization: Geochemica et Cosmochimica Acta, v. 37, p. 269-282.

Baker-Blocker, A., E. Callender, P. D. Josephson, 1975, Trace element and organic carbon content of surface sediment from Grand Traverse Bay, Lake Michigan: Geological Society of America Bulletin, v. 86, p. 1358-1362.

Bellaire, F. R., and J. C. Ayers, 1967, Current patterns and lake slope: Proceedings of the 10th Conference on Great Lakes Research, p. 251-263.

Biggins, P.D.E., and R. M. Harrison, 1979, Atmospheric chemistry of automotive lead: Environmental Science and Technology, v. 13, p. 558-565.

Bortleson, G. C., 1971, The chemical investigation of Recent sediments from Wisconsin lakes: Ph.D. thesis, Water Chemistry Department, University of Wisconsin, Madison, WI, 278 p.

Bortleson, G. C., and F. G. Lee, 1972, Recent sediment history of Lake Mendota, Wis.: Environmental Science and Technology, v. 6, p. 799-808.

Bortleson, G. C., F. G. Lee, 1975, Recent sedimentary history of Lake Monona, Wis.: Water, Air and Soil Pollution, v. 4, p. 89-98.

Callender, Edward, 1969, Geochemical characteristics of Lakes Michigan and Superior sediments: Proceedings of the 12th Conference on Great Lakes Research, p. 124-160.

Capobianco, J. A., 1974, Carbon analysis of lake sediments using a Leco IR-12 analyzer: Canada Centre for Inland Waters Internal Report, Burlington, Ontario.

Christensen, E. R., and N. W. Chien, Fluxes of arsenic, lead, and cadmium to Green Bay and Lake Michigan: Environmental Science and Technology, in press.

Cline, J. T., and S. R. Upchurch, 1973, Mode of heavy metal migration in the upper strata of lake sediment: Proceedings of the 16th Conference Great Lakes Research, p. 349-356.

Coakley, J. P., S. Beal, 1969, Computer program for sediment particle-size analysis (SEDAN): Canada Inland Waters, Directors Report Series No. 20, 33 p.

Cole, Gerald A., 1975, Textbook of limnology: C. U. Mosby Company, St. Louis, 283 p.

Computing Services Office, 1979, SOUPAC programs descriptions, C. S. O. Volume 9 (USER): University of Illinois, Urbana, IL.

Cook, D. O., and D. W. Felix, 1975, Ferromanganese deposits in the Saranac Lake: Journal of Great Lakes Research, v. 1, p. 10-17.

Cronan, D. S., and R. L. Thomas, 1972, Geochemistry of ferromanganese oxide concretions and associated deposits in Lake Ontario: Geological Society of America Bulletin, v. 83, p. 1493-1501.

Damiani, V., T. W. Morton, and R. L. Thomas, 1973, Freshwater ferromanganese nodules from the Big Bay section of the Bay of Quinte, Northern Lake Ontario: Proceedings of the 16th Conference Great Lakes Research, p. 397-403.

Dorr, J. A., and D. F., Eschman, 1970, Geology of Michigan: University of Michigan Press, Ann Arbor, MI, 476 p.

Dungworth, G. M., J. Z. Thijssen, W. Van der Velden, and A. W. Schwartz, 1977, Distribution of amino acids, amino sugar, purines and pyrimidines in a Lake Ontario core: Chemical Geology, v. 19, p. 295-308.

Edgington, D. N., and E. Callender, 1970, Minor element geochemistry of Lake Michigan ferromanganese nodules: Earth and Planetary Science Letters, v. 8, p. 97-100.

Edginton, D. N., and J. A. Robbins, 1976, Records of lead deposition in Lake Michigan sediments since 1800: Environmental Science and Technology, v. 10, p. 266-274.

Emery, K. O., 1951, Bathymetric chart of Lake Michigan: University of Minnesota Institute of Technology, Engineering Experimental Station Technical Paper 77.

Fitchko, J., and T. C. Huchinson, 1975, A comparative study of heavy metal concentrations in river mouth sediments around the Great Lakes: Journal of Great Lakes Research, v. 1, p. 46-78.

Frye, J. C., and N. F. Shimp, 1973, Major, minor, and trace elements in sediments of late Pleistocene Lake Saline compared with those in Lake Michigan sediments: Illinois State Geological Survey, Environmental Geology Notes, no. 60, 14 p.

Gatz, D. F., 1975, Pollutant aerosol deposition into southern Lake Michigan: Water, Air, and Soil Pollution, v. 5, p. 239-251.

Gatz, D. F., and S. A. Changnon, Jr., 1976, Atmospheric environment of the Lake Michigan drainage basin, vol. 8: Environmental status of the Lake Michigan region: Argonne National Laboratory, ES-40, 164 p.

Gorham, E., W. G. Lund, J. E. Sanger, W. Dean, 1974, Some relationships between algal standing crop, water chemistry, and sediment chemistry in the English Lakes: Limnology and Oceanography, v. 19, p. 601-617.

Gross, D. L., J. A. Lineback, W. A. White, N. J. Ayer, C. Collinson, and H. V. Leland, 1970, Preliminary stratigraphy of unconsolidated sediments from the southwestern part of Lake Michigan: Illinois State Geological Survey, Environmental Geology Notes, no. 30, 20 p.

Harriss, R. C., and A. G. Troup, 1969, Chemistry and origin of freshwater ferromanganese concretions: Limnology and Oceanography, v. 20, p. 702-712.

Harrison, P. R., K. A. Rahn, R. Dams, J. A. Robbins, J. W. Winchester, S. S. Brar, and D. M. Nelson, 1971, Areawide trace metal concentrations measured by multielemental neutron activation analysis: Air Pollution Control Association Journal, v. 21, p. 563-570.

Hopke, P. K., 1976, The application of multivariate analysis of interpretation of the chemical and physical analysis of lake sediments: Journal of Environmental Science and Health, v. 11, p. 367-383.

Hopke, P. K., D. F. Ruppert, P. R. Clute, W. J. Metzger, and D. J. Crowley, 1976, Geochemical profile of Chautauqua Lake sediments: Journal of Radioanalytical Chemistry, v. 29, p. 39-59.

Hough, J. L., 1958, Geology of the Great Lakes: University of Illinois Press, Urbana, 313 p.

Hutchinson, G. E., 1957, A treatise on limnology, vol. 1: Geography, Physics and Chemistry: John Wiley & Sons, New York, 1015 p.

Ishiwatari, R., 1973, Chemical characterization of fractionated humic acids from lake and marine sediments: Chemical Geology, v. 12, p. 113-126.

Jackson, R. G., and I. Nichol, 1975, Factors affecting trace element distribution in lake sediments in the Yellow Knife area, NWT, Canada: International Association of Theoretical Applied Limnology, v. 19, part 1, p. 308-316.

Kemp, A.L.W., 1971, Organic carbon and nitrogen in the surface sediments of Lakes Ontario, Erie and Huron: Journal of Sedimentary Petrology, v. 41, p. 537-548.

Kemp, A.L.W., G. A. MacInnis, and N. S. Harper, 1977, Sedimentation rates and a revised sediment budget for Lake Erie: Journal of Great Lakes Research, v. 3, p. 221-233.

Kemp, A.L.W., and A. Mudrochova, 1973, The distribution and nature of amino acids and other nitrogen containing compounds in Lake Ontario and surface sediments: Geochimica et Cosmochimica Acta, v. 37, p. 2191-2206.

Kemp, A.L.W., and R. L. Thomas, 1976, Impact of man's activities on the chemical composition in the sediments of Lakes Ontario, Erie and Huron: Water, Air, and Soil Pollution, v. 5, 469-490.

Kemp, A.L.W., R. L. Thomas, C. I. Dell, and J. M. Jaquet, 1976, Cultural impact on the geochemistry of sediments in Lake Erie: Journal of Fisheries Resources Board of Canada, v. 33, p. 440-462.

King, J. E., J. A. Lineback, and D. L. Gross, 1976, Palynology and sedimentology of Holocene deposits in southern Lake Michigan: Illinois State Geological Survey, Circular 496, 24 p.

Klein, D. H., 1975, Fluxes, residence times and source of some elements to Lake Michigan: Water, Air, and Soil Pollution, v. 4, p. 3-8.

Kothandaraman, V., R. L. Evans, N. G. Bhowmik, J. B. Stall, D. L. Gross, J. A. Lineback, and G. B. Dreher, 1977, Fox Chain of Lakes investigation and water quality management plan: Cooperative Resources Report 5, Illinois State Geological Survey and Illinois State Water Survey, 200 p.

Krumbein, W. C., and F. J. Pettijohn, 1938, Manual of sedimentary petrography: Appleton-Century-Crofts, New York, 549 p.

Leland, H. V., W. N. Bruce, and N. F. Shimp, 1973, Chlorinated hydrocarbon insecticide in sediments of southern Lake Michigan: Environmental Science and Technology, v. 9, p. 833-838.

Leland, H. V., and N. F. Shimp, 1974, Distribution of selected trace metals in southern Lake Michigan and lower Green Bay: University of Illinois Water Resources Center Research Report, no. 84, 27 p.

Leland, H. V., S. S. Shukla, and N. F. Shimp, 1973, Factors affecting distribution of lead and other trace elements in sediments of southern Lake Michigan: *in* Trace metals and metal-organic interactions in natural waters: Ann Arbor Science, Ann Arbor, MI, p. 89-138.

Lerman, A., ed., 1978, Lakes: Chemistry, geology, and physics: Springer-Verlag, New York, 364 p.

Lineback, J. A., C. I. Dell, and D. L. Gross, 1979, Glacial and postglacial sediments in Lakes Superior and Michigan: Geological Society of America Bulletin, Part I, v. 90, p. 781-791.

Lineback, J. A. and D. L. Gross, 1972, Depositional patterns facies and trace element accumulation in the Waukegan member of the late Pleistocene Lake Michigan formation in southern Lake Michigan: Illinois State Geological Survey, Environmental Geology Notes, no. 58, 25 p.

Lineback, J. A., D. L. Gross, and R. P. Meyer, 1974, Glacial tills under Lake Michigan: Illinois State Geological Survey, Environmental Geology Notes, no. 69, 48 p.

Martin, J. H., and G. A. Knauer, 1973, The elemental composition of plankton: Geochimica et Cosmochimica Acta, v. 37, p. 1639-1654.

Mason, B., 1966, Principles of geochemistry: John Wiley & Sons, New York, 329 p.

Mortimer, C. H., 1975, Physical limnology of Lake Michigan, Vol. 2: Environmental status of Lake Michigan: Argonne National Laboratory, Report no. ANL/ES-40, 121 p.

Moyers, J. L., W. H. Zoller, R. A. Duce, and G. L. Hoffman, 1972, Gaseous bromine and particulate lead, vanadium and bromine in a polluted atmosphere: Environmental Science and Technology, v. 5, p. 68-71.

Mudroch, A., 1977, Determination of major elements in lake and river bottoms sediments by Philips PW 1220C X-ray fluorescence spectrometer: Canada Centre for Inland Waters, Burlington, Ontario.

Nissenbaum, A., and D. J. Swaine, 1976, Organic matter-metal interactions in recent sediments: The role of humic substances: Geochimica et Cosmochimica Acta, v. 40, p. 809-816.

Ondov, J. M., 1974, A study of trace elements on particulates from motor vehicles: Ph.D. thesis, University of Maryland, College Park, MD, 322 p.

Otsuki, A., and T. Hanya, 1967, Some precursors of humic acid in recent lake sediment suggested by infra-red spectra: Geochimica et Cosmochimica Acta, v. 31, p. 1505-1515.

Parks, J. M., 1969, Fortran IV program for Q-mode cluster analysis on distance function with printed dendrogram: Operation Resarch Section, Kansas Geological Survey, 32 p.

Reeves, C. C., Jr., 1968, Introduction to paleolimnology: Developments in Sedimentology, Vol. 11: Elsevier, New York, 228 p.

Reuter, J. H., and E. M. Perdue, 1977, Importance of heavy metal-organic matter interactions in natural waters: Geochimica et Cosmochimica Acta, v. 41, p. 325-334.

Robbins, J. A., and E. Callender, 1975, Diagenesis of manganese in Lake Michigan sediments: American Scientist, v. 275, p. 512-533.

Robbins, J. A., and D. N. Edgington, 1975, Determination of recent sedimentation rates in Lake Michigan using Pb-210 and Cs-137: Geochimica et Cosmochimica Acta, v. 39, p. 285-304.

Robbins, J. A., and D. N. Edgington, 1976, Distribution of selected chemical elements in the sediments of southern Lake Michigan: Argonne National Laboratory Report no. 88, Part III, p. 65-71.

Robbins, J. A., E. Landstrom, and M. Wahlgren, 1972, Tributary inputs of soluble trace metals to Lake Michigan: Proceedings of 15th Conference of Great Lakes Research, p. 270-296.

Rossmann, R., and E. Callender, 1969, Geochemistry of Lake Michigan manganese nodules: Proceedings of 12th Conference of Great Lakes Research, p. 306-316.

Rossmann, R., E. Callender, and C. J. Bowser, 1972, Inter-element geochemistry of Lake Michigan ferromanganese nodules: 24th International Geological Congress, Montreal, Canada, p. 336-341.

Schnitzer, M., and S. U. Khan, 1972, Humic substances in the environment, Marcel Dekker, New York, 327 p.

Schnitzer, M., and S.I.M. Skinner, 1967, Organometallic interactions in soils: Seven stability constants of Pb, Ni, Mn, Co, Ca, and Mg-fulvic acid complexes: Soil Science, v. 103, p. 247-252.

Shepard, F. P., 1937, Origin of the Great Lakes Basins: Journal of Geology, v. 45, p. 76-88.

Shepard, F. P., 1954, Nomenclature based on sand-silt-clay ratios, Journal of Sedimentary Petrology, v. 24, p. 151-158.

Shimp, N. F., H. V. Leland, and W. A. White, 1970, Distribution of major, minor and trace constituents in unconsolidated sediments from southern Lake Michigan: Illinois State Geological Survey, Environmental Geology Notes, no. 32, 19 p.

Shimp, N. F., J. A. Schleicher, R. R. Ruch, D. B. Heck, and H. V. Leland, 1971, Trace element and organic carbon accumulation in the most recent sediments of southern Lake Michigan: Illinois State Geological Survey, Environmental Geology Notes, no. 41, 25 p.

Sievering, H., M. Dave, D. A. Dolske, R. C. Hughes, and P. McCoy, 1979, An experimental study of Lake Michigan loading by aerosol transport and dry deposition in the southern Lake Michigan Basin, Final Report EPA-905/4-79-016, 179 p.

Silver, M. L., and J. A. Lineback, 1972, Velocity of sound in sediments cored from southern Lake Michigan: Illinois State Geological Survey, Circular 475, 18 p.

Sly, P. G., 1969, Bottom sediment sampling: Proceedings of 12th Conference of Great Lakes Research, p. 883-898.

Sly, P. G., 1978, Sedimentary processes in lakes, *in* Lerman, A. [ed.] Lakes: Chemistry, geology, and physics: Springer-Verlag, New York, p. 65-84.

Sly, P. G., and R. L. Thomas, 1974, Review of geological research as it relates to an understanding of Great Lakes limnology: Journal of Fisheries Research Board, Canada, v. 31, p. 795-825.

Stanley, G. M., 1938, The submerged valley through Mackinac Straits: Journal of Geology, v. 46, p. 966-974.

Stumm, W., and J. J. Morgan, 1970, Aquatic chemistry: Wiley Interscience, 583 p.

Thomas, R. L., and D. J. Jaquet, 1975, The surficial sediments of Lake Superior: Proceedings of 9th International Congress of Sedimentology, Nice, France, 7 p.

Thomas, R. L., J. M. Jaquet, A.L.W. Kemp, and C.F.M. Lewis, 1976, Surficial sediments of Lake Erie: Journal of Fisheries Research Board, Canada, v. 33, p. 385-403.

Thomas, R. L., A.L.W. Kemp, and C.F.M. Lewis, 1972, Distribution, composition, and characteristics of the surficial sediments of Lake Ontario: Journal of Sedimentary Petrology, v. 42, p. 66-81.

Thomas, R. L., A.L.W. Kemp, and C.F.M. Lewis, 1973, Surficial sediments of Lake Huron: Canadian Journal of Earth Sciences, v. 101, p. 226-271.

Torrey, M. S., 1976, Chemistry of Lake Michigan, Vol. 3: Environmental status of the Lake Michigan region: Argonne National Laboratory Report no. ANL/ES-40, 418 p.

Vallentyne, J. R., 1957, The molecular nature of organic matter in lakes and oceans, with lesser reference to sewage and terrestrial soil: Journal of the Fisheries Research Board of Canada, v. 14, no. 1, p. 33-82.

Vallentyne, J. R., 1969, Sedimentary organic matter and paleolimnology: International Association of Theoretical and Applied Limnclogy Communications, v. 17, p. 104-110.

Van der Velden, W., and A. W. Schwartz, 1976, Purines, pyrimidines, and organic carbon in lake sediments: A comparison of sediments from lakes of varying degrees of euthrophications: Chemical Geology, v. 18, p. 273-284.

Vinogradov, A. P., 1959, The geochemistry of rare and dispersed chemical elements in soils: 2nd ed., Consultants Bureau, New York, 209 p.

Wetzel, R. G., 1968, Dissolved organic matter and phytoplankton productivity in marl lakes: International Association of Theoretical and Applied Limnology Communications, v. 14, p. 261-270.

Wetzel, R. G., 1975, Limnology: W. B. Saunders Co., Philadelphia, 494 p.

Wickham, J. T., D. L. Gross, J. A. Lineback, and R. L. Thomas, 1978, Late quaternary sediments of Lake Michigan: Illinois State Geological Survey, Environmental Geology Notes, no. 84, 26 p.

Winchester, J. W., and G. D. Nifong, 1971, Water pollution in Lake Michigan by trace elements from pollution aerosol fallout: Water, Air and Soil Pollution, v. 1, p. 50-64.

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